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IMPACT AND OPERATIONAL TESTS OF THE CONTAINER HOPPER

M. J. Wolfe, et al

Naval Civil Engineering Laboratory
Port Hueneme, California

November 1973

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There were two major phases in the development of the hopper. The first consisted of impact tests on one of the hopper shock absorbers. High speed movies were taken of the impacts and measurements made of the shock absorber deflections. The test data was combined with a computer program for stress calculations. From the results it was concluded that fully-loaded, 20-foot long van container would not be damaged if it should strike a hopper absorber at three feet per second or less.

The second phase was a fully operational evaluation of the hopper during the OSDOC II (Offshore Discharge of Containership II) exercise in which a containership anchored one mile off the Virginia coast was unloaded with a floating crane. The crane lowered containers through the hopper onto flatbed semi-trailers, MILVAN chassis, and tandem rigs. Like the crane, the hopper and trucks were on a floating platform. Loading times as short as one minute were achieved.

It was concluded that the hopper greatly aids the placing of containers by floating crane onto truck trailers at sea. Moreover, the hopper is an uncomplicated piece of equipment which has the durability required for container handling operations.

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INTRODUCTION

Because of relative motions between cranes and lighters, attempts to load maritime van containers onto truck trailers while at sea have met with little success. To improve this situation the container hopper was conceived and developed by the Studies and Requirements Division of the Marine Corps Development and Education Command, the Naval Facilities Engineering Command, the Naval Civil Engineering Laboratory, and private industry.

This report covers the development of the hopper from the beginning through final operational evaluation. It is divided into six sections:

I. GENERAL DESCRIPTION OF THE HOPPER - This section is a description of the hopper and how it operates. Also included is a discussion of the design criteria.

II. IMPACT TESTS OF THE HOPPER - One of the primary functions of the hopper is to attenuate the swinging motions of a maritime van container suspended by a crane. A shock absorber system was designed to accomplish this attenuation without damaging the container. To test the design, impact tests were run in which a hopper shock absorber was struck with a large weight. The test execution, data gathering, and calculations are discussed in this section.

III. OPERATIONAL TESTS OF THE HOPPER - OSDOC II - The hopper was used in Off-Shore Discharge of Containership exercise (OSDOC II) in early October 1972 at Fort Story, Virginia. OSDOC II was a combined Army/Navy and Marine Corps exercise to test various means of unloading a containership anchored offshore. The hopper was a component in one of the unloading systems tested and, in fact, it was designed and fabricated to be used in OSDOC II. This section describes the use of the hopper at OSDOC II, i. e., the fully operational test. Included are descriptions of the arrangement of the equipment, the truck loading times, and comments of the operating crew.

IV. POST-OSDOC II HOPPER TESTS - At the completion of OSDOC II it was decided that more testing of the hopper was in order, primarily because it was used only two dozen times at sea during OSDOC II. Additional tests were done in the harbor at Little Creek, Virginia, under conditions simulating as best possible the OSDOC II operation. The objective of the post-OSDOC II tests was to gather more data on truck loading times through the hopper. As a baseline for comparison, the truck was also loaded without using the hopper.

V. ESTIMATE OF LOADING CYCLE TIMES AT SEA - As implied above, the hopper was not used enough at sea during OSDOC II to make a definitive statement on what loading times would be possible after the crew had sufficient practice to be well-along the learning curve. An estimate is made in this section of the probable loading at sea by combining data from the OSDOC II and post-OSDOC II tests. An assumption is made that as far as operation of the hopper is concerned, there is no difference between operation at sea and operation in the harbor where most of the data was taken.

VI. CONCLUSIONS - The sixth and final section lists the conclusions on the hopper design and operation derived from all the impact, OSDOC II, and post-OSDOC II tests.

I. GENERAL DESCRIPTION OF THE HOPPER

The hopper is designed to be used at sea, mounted on a barge as shown in Figure 1. When in operation, the hopper-equipped barge is moored to a crane barge which in turn is moored to a containership (see Figure 2). A truck will be driven off a causeway and positioned under the hopper, as shown in Figure 3. The crane will remove a container from the cell or deck of the containership and lower it down through the hopper and onto the truck trailer waiting below. Figure 3 shows such a loading.

In port and similar land-based operations the container could be lowered directly onto a trailer without benefit of the hopper. At sea, however, wave and swell action will induce motions in the crane barge and, therefore, the container suspended from the crane. These motions make it extremely difficult to position the container directly onto a trailer. Also, the vessel supporting the trailer will be experiencing wave induced motions which compound the loading difficulty. Even if the crane and truck were on the same floating platform the loading operation could still be difficult due to pitching and swinging of the container which is suspended by the crane's cables. The loading is particularly difficult if the trailer is a MILVAN chassis, which requires that the container be placed with a fair amount of accuracy on four protruding twist locks.

The hopper will do at least three things to facilitate placing the container onto a trailer:

(1) present a large target for the crane operator as he lowers the container;

(2) stop any horizontal movement of the container which may occur due to movement of the vessel supporting the crane; and

(3) maintain the container directly over the trailer as it is lowered into position.

Figure 1. Hopper on 7x15 pontoon barge. In the immediate background the DeLong barge and truck crane can be seen. The bridge of the containership can be seen in the far background.

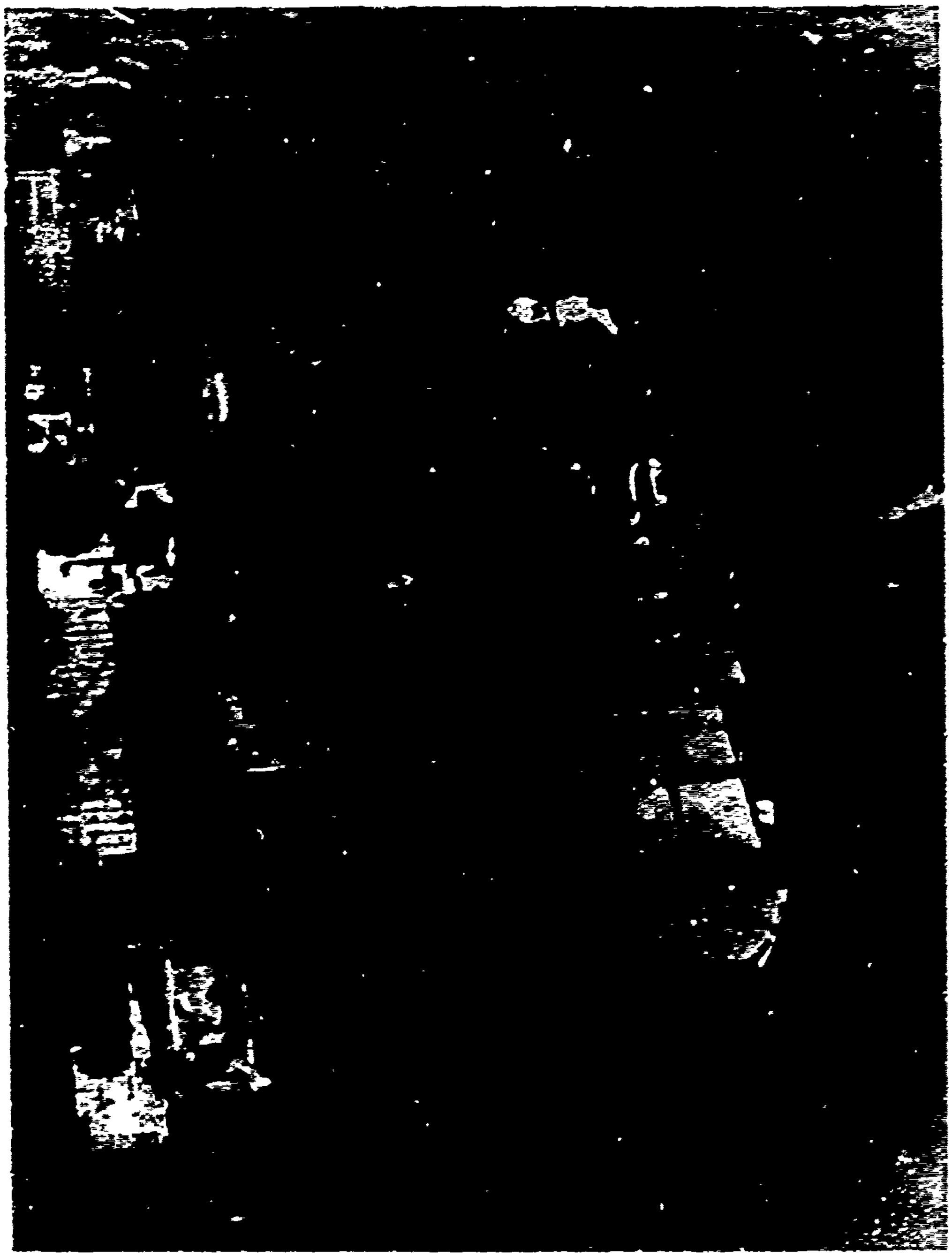


Figure 2. Aerial view of the OSDOC II test site. The hopper barge can be seen in the left center of the photograph. One causeway with empty trucks has been connected to the hopper barge in the upper left. The (three) trucks loaded so far have driven forward onto the causeway on the other side (lower left) of the hopper barge.

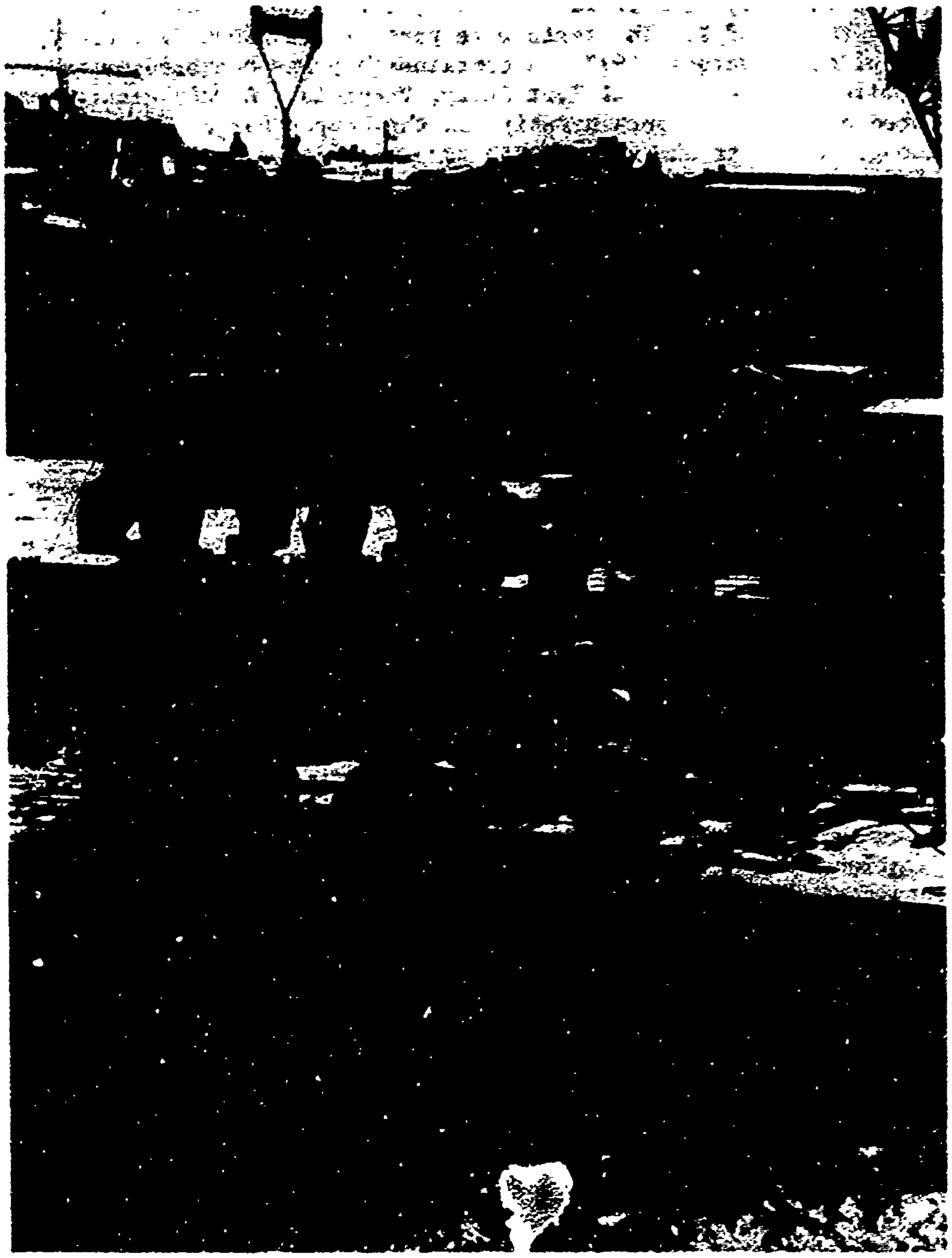


Figure 3. Aerial view of a truck being loaded through the hopper. The trailer is a MILVAN chassis and the tractor a M818.

In the only time it was used at sea the hopper was used as shown in Figures 1 and 2. The tests were part of the OSDOC II operation which took place in October 1972. A containership was anchored approximately one mile off the beach at Fort Story, Virginia. A DeLong barge was moored next to the containership and the hopper barge moored to the DeLong. A P&H truck crane of 250 tons capacity was mounted on the DeLong.

There were three primary design criteria for the hopper. It was decided that the system would arrest the movement of an 8'x8'x20' container weighing 44,800 pounds moving at a maximum horizontal velocity of three feet per second. An additional criterion imposed on the design of the hopper was that, in arresting the motion, the container was in no way damaged by the hopper system upon impact. Finally, the hopper had to be capable of guiding the container squarely onto a trailer parked below.

The three foot per second maximum velocity was chosen before the hopper was built. It is an arbitrary figure which most observers felt was a good approximation of the maximum velocity at which a container would swing at it was suspended from a crane. For example, if the container was suspended at the end of a 150 foot line, it would have to swing through an amplitude (1/2 swing) of nearly 7 feet to reach three feet per second at the point of maximum velocity (the bottom of the swing). This is a relatively large swing, particularly if taglines are used to restrain the load. In addition, crane operating practice dictates that the load not be allowed to swing out from under the boom tip.

Adding these factors together, it was concluded that the containers would not strike the bumper at more than three feet per second. This proved to be a conservative estimate because in all loadings during operational tests using the barge crane (OSDOC II) and afterwards, the containers had little horizontal motion if the crane was not swinging the boom. This lack of pendulating motion is discussed in detail in Section III.

The hopper consists of two major elements: the top and the base. Each is discussed below.

HOPPER TOP

The top, as illustrated in Figure 4, consists of six bumpers mounted on a rectangular frame. As shown in Figure 5. each bumper consists of a curved pipe which pivots about its lowest point. The rotating motion of the arm is restricted by a dampening device constructed of two truck tires. The truck tires are bolted to each other, the lower tire bolted to the fixed inclined plate, and the upper tire bolted to a similar plate on the arm.

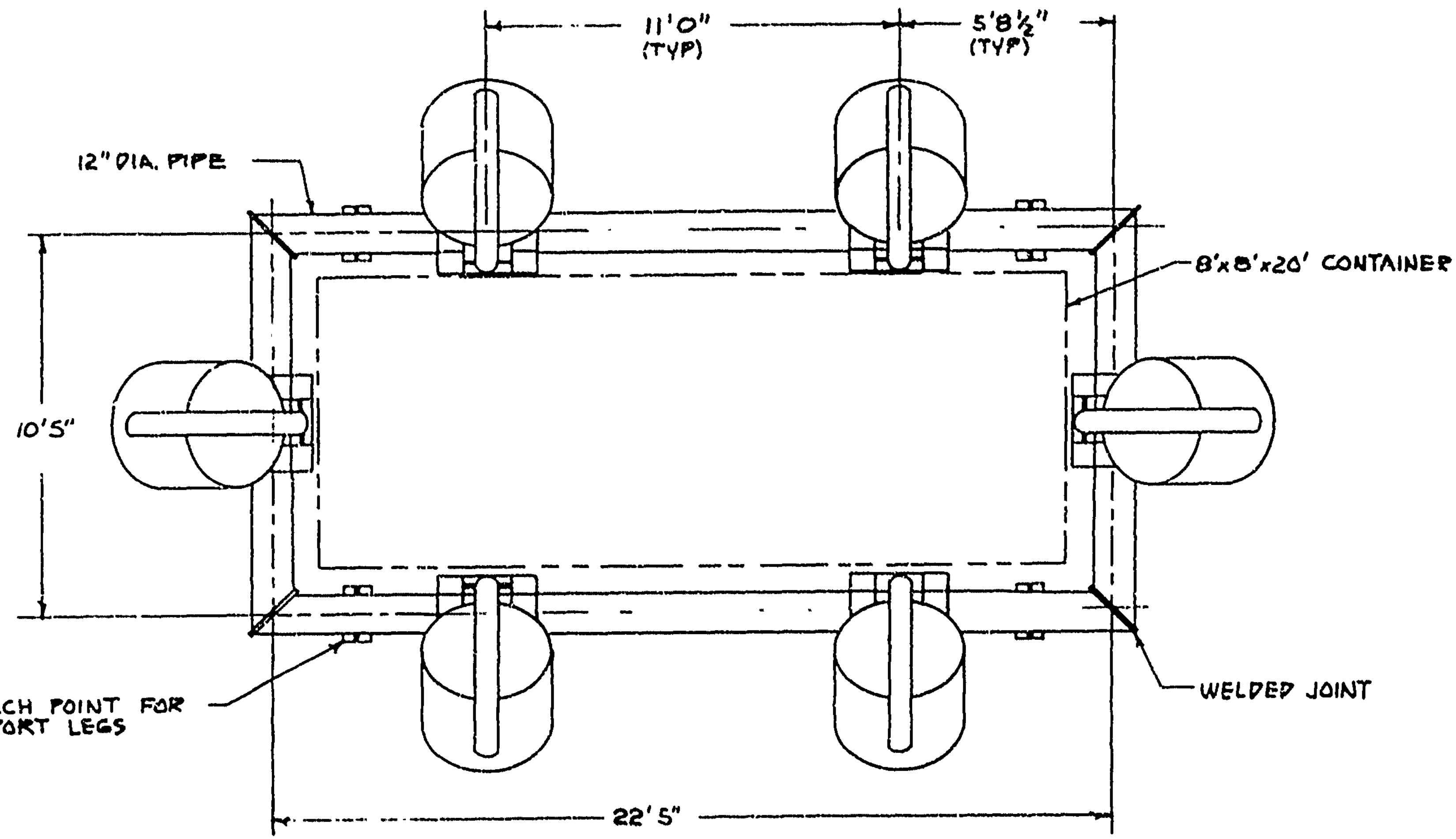


Figure 4. Arrangement of bumpers on pipe support frame (plan view).

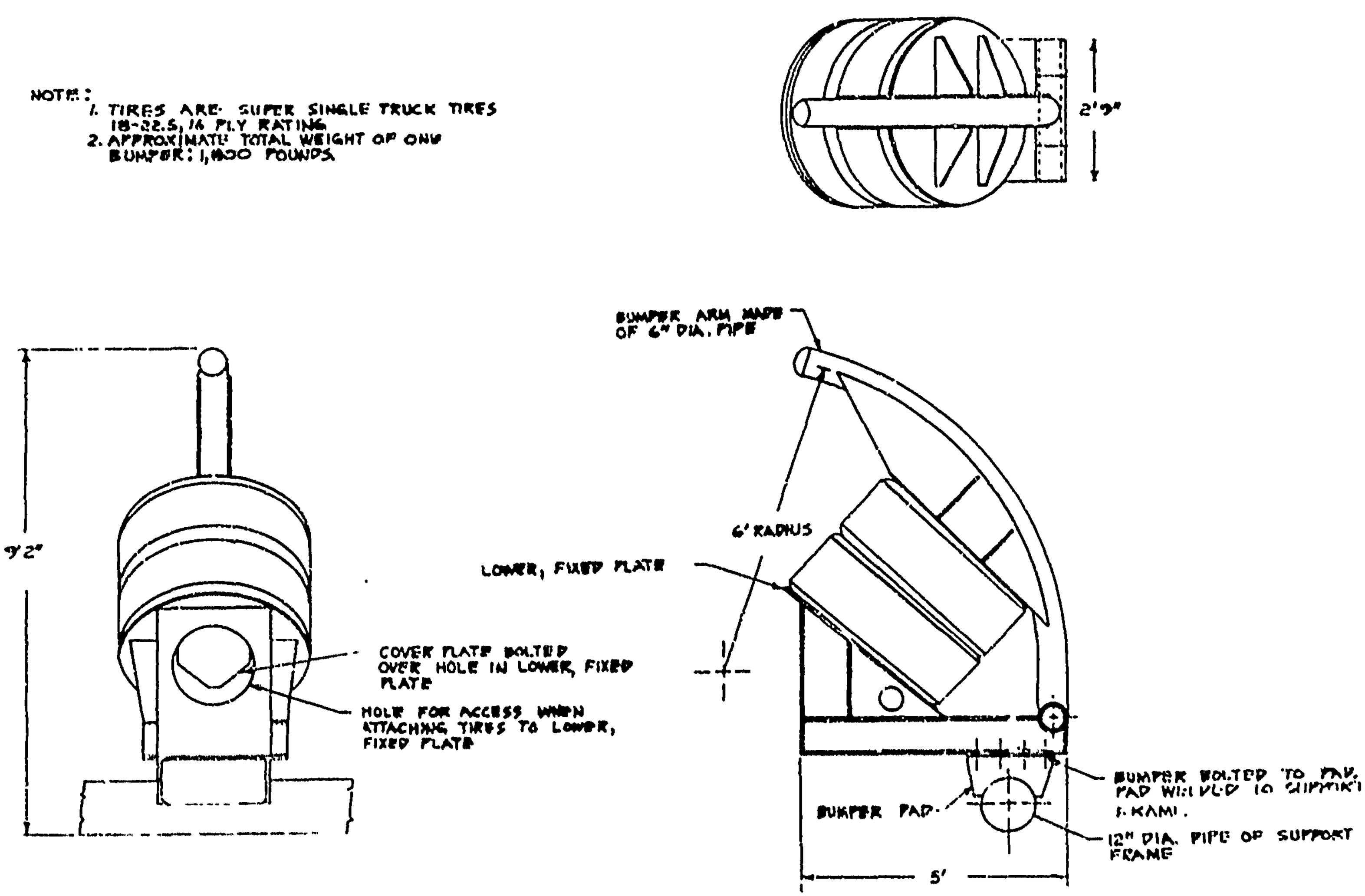


Figure 5. Details of hopper bumper.

The tires provide the cushioning or damping effect when the arm is struck by a suspended load. They are compressed by the plate on the arm as the latter rotates under the dynamic forces of the moving load. Figure 6 illustrates the action of the arm and tires during impact. This shock absorbing feature allows attenuation of the horizontal motion of the swinging container at a considerable savings in total weight over a device which would rely on a rigid structure to absorb the energy. Moreover, the resiliency of the system results in considerably smaller shock loads on the container than a rigid structure.

HOPPER BASE

The hopper base is designed to accomplish two functions: (1) elevate and support the top and (2) provide the fine positioning capability required to place the container on the truck trailer.

As shown in Figure 7, the base consists of four legs with bracing. On each leg there is a guide assembly which can be manually rotated in and out of the loading position. In Figure 1 the guide assemblies are in the open position. Figures 8, 9, and 10 show the details of a guide assembly. Each assembly consists of two movable flared wings which can be moved back and forth over each corner of the trailer. As can be seen in Figure 9, the wings are moved by a screw mechanism which is actuated by turning a wheel. One wing provides forward/aft adjustment and other side-to-side adjustment.

The screw mechanism for fore and aft control is a straight-through screw which pushes or pulls on the lower portion of the hinged wing. The wing is hinged at the top and rotates about the hinge. For the side-to-side wing it was necessary to put in bevel gears to make a right angle turn. This arrangement makes it possible to control the two wings from one location, since the wheels are located next to each other.

The lower edges of the wings meet at a 105° angle (see the top view in Figure 9). This provides extra clearance which permits the operators to swing the guide assembly to the open position without withdrawing the hinged wings after the container is positioned on the trailer.

To help center the truck under the hopper two 20-foot long positioning rails were welded to the pontoon deck. These are shown in Figure 7 and can be partially seen in Figure 1. The distance between them is slightly less than the distance between the inside of the tires on the MILVAN chassis.

Positioning the truck lengthwise under the hopper is accomplished by stopping the truck at a pre-determined point, marked with a line painted on the deck. Once the truck is positioned, the guide assemblies are swung into the loading position and the container loaded onto the trailer. The guide assemblies must be swung to the open position before a loaded truck can proceed from under the hopper.

(a) Bumper at rest

(b) Bumper during loading. Note how tires are crushed.

Figure 6. Action of hopper bumper under impact loading.

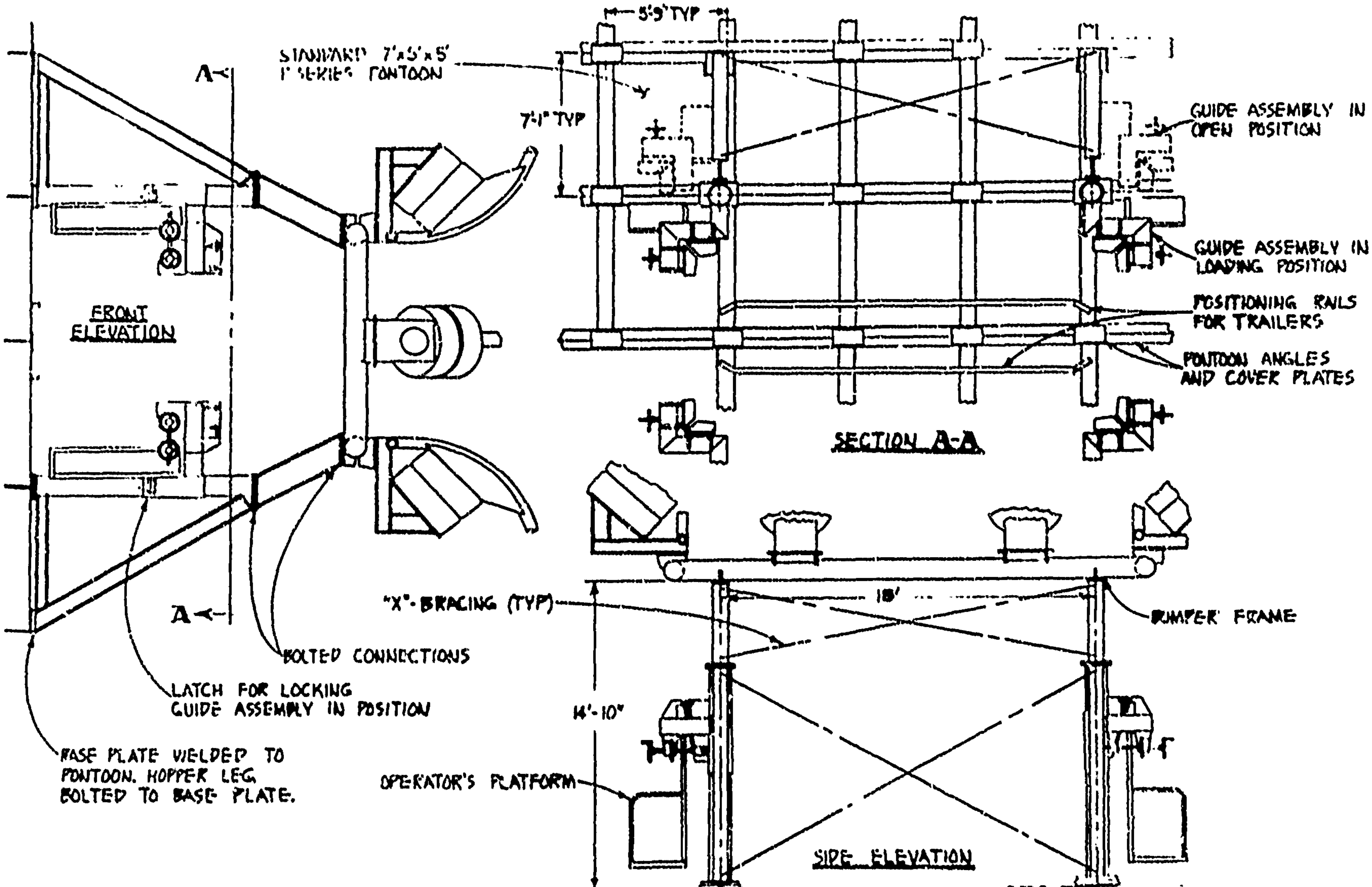


Figure 7. Details of hopper mounting on 7x15 barge.

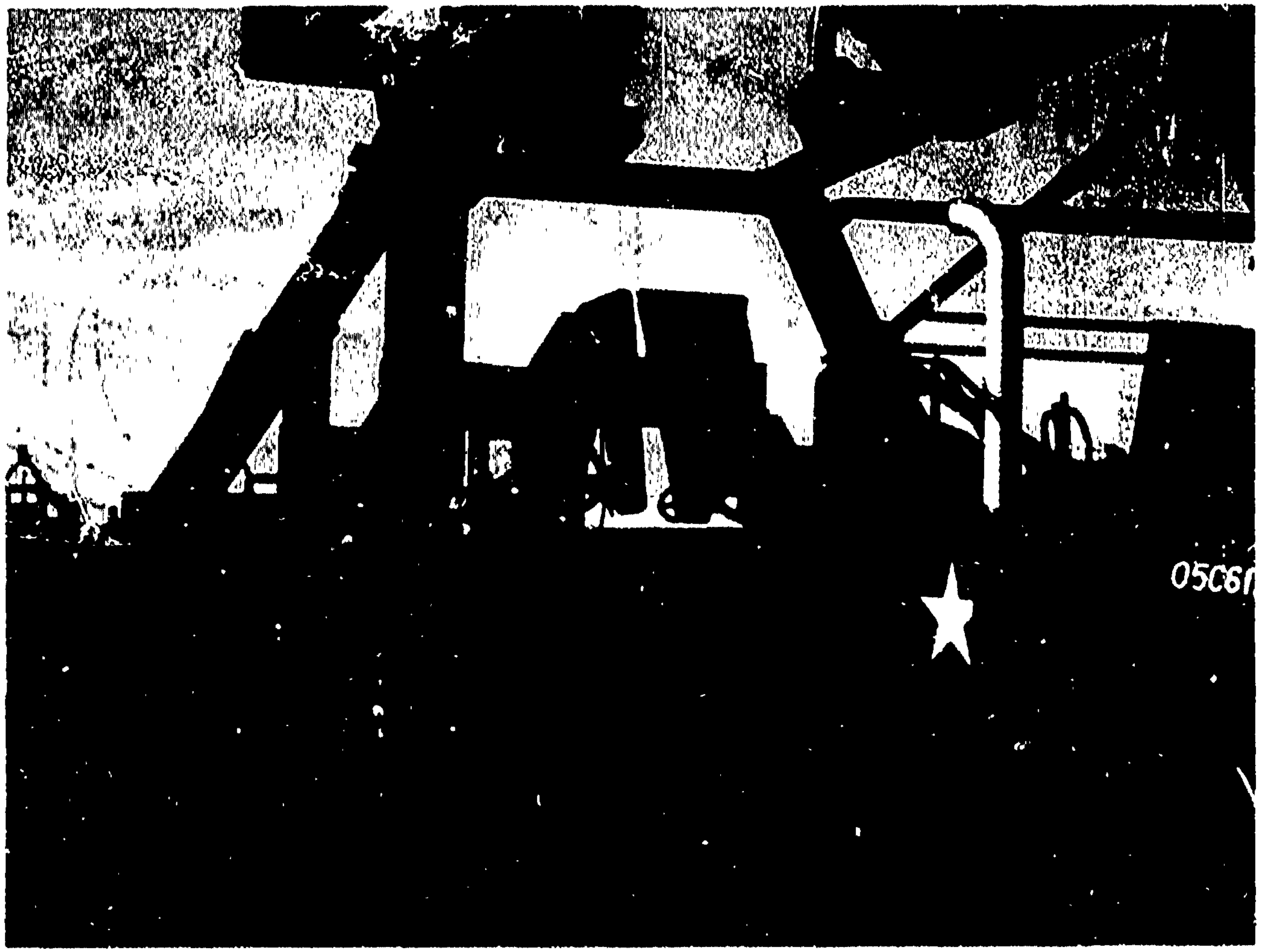


Figure 8. Close-up view of a truck in position, ready to be loaded. Man in foreground is standing on the operator's platform, ready to operate fine positioning assembly.

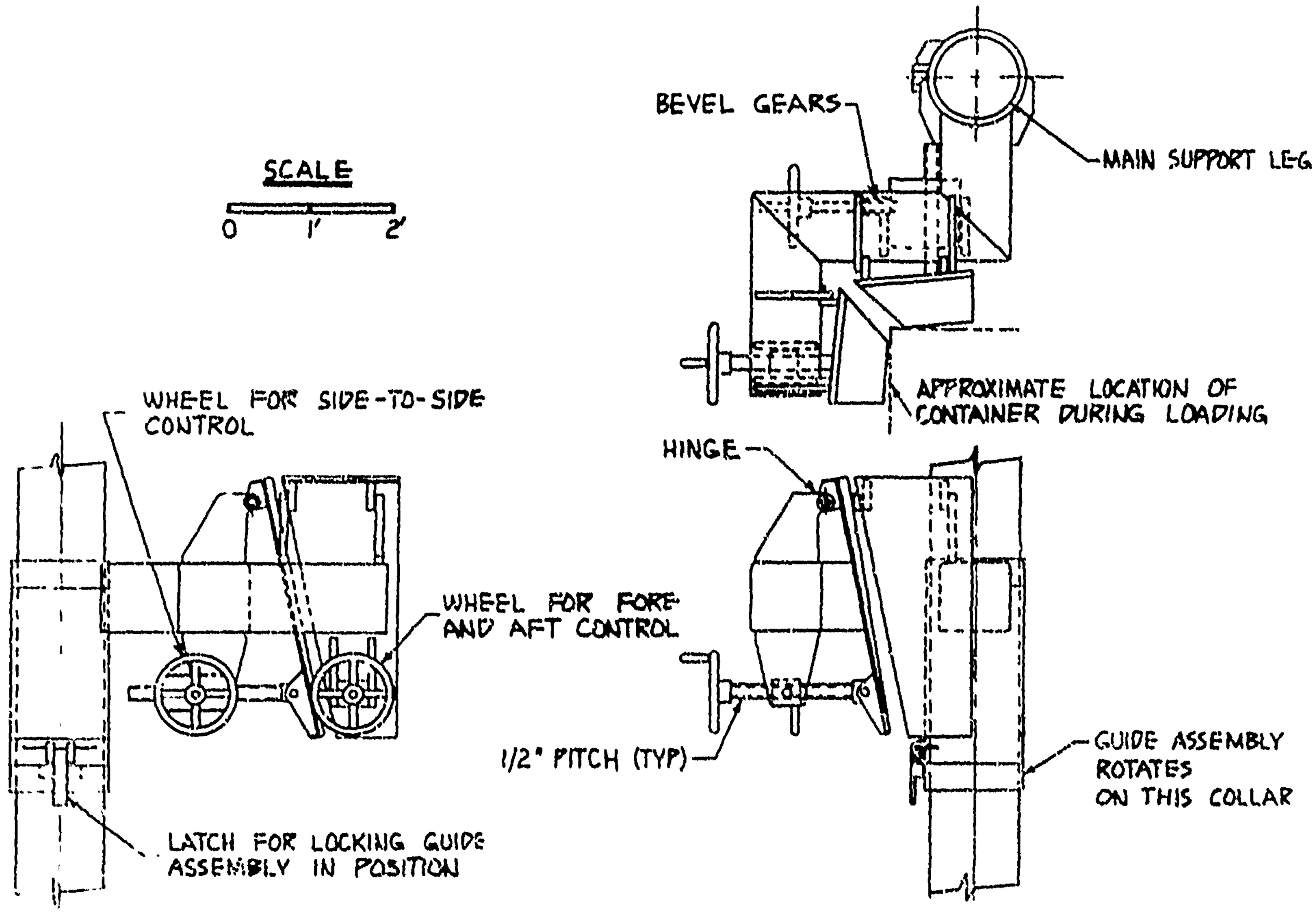


Figure 9. Details of the fine positioning guide assembly.

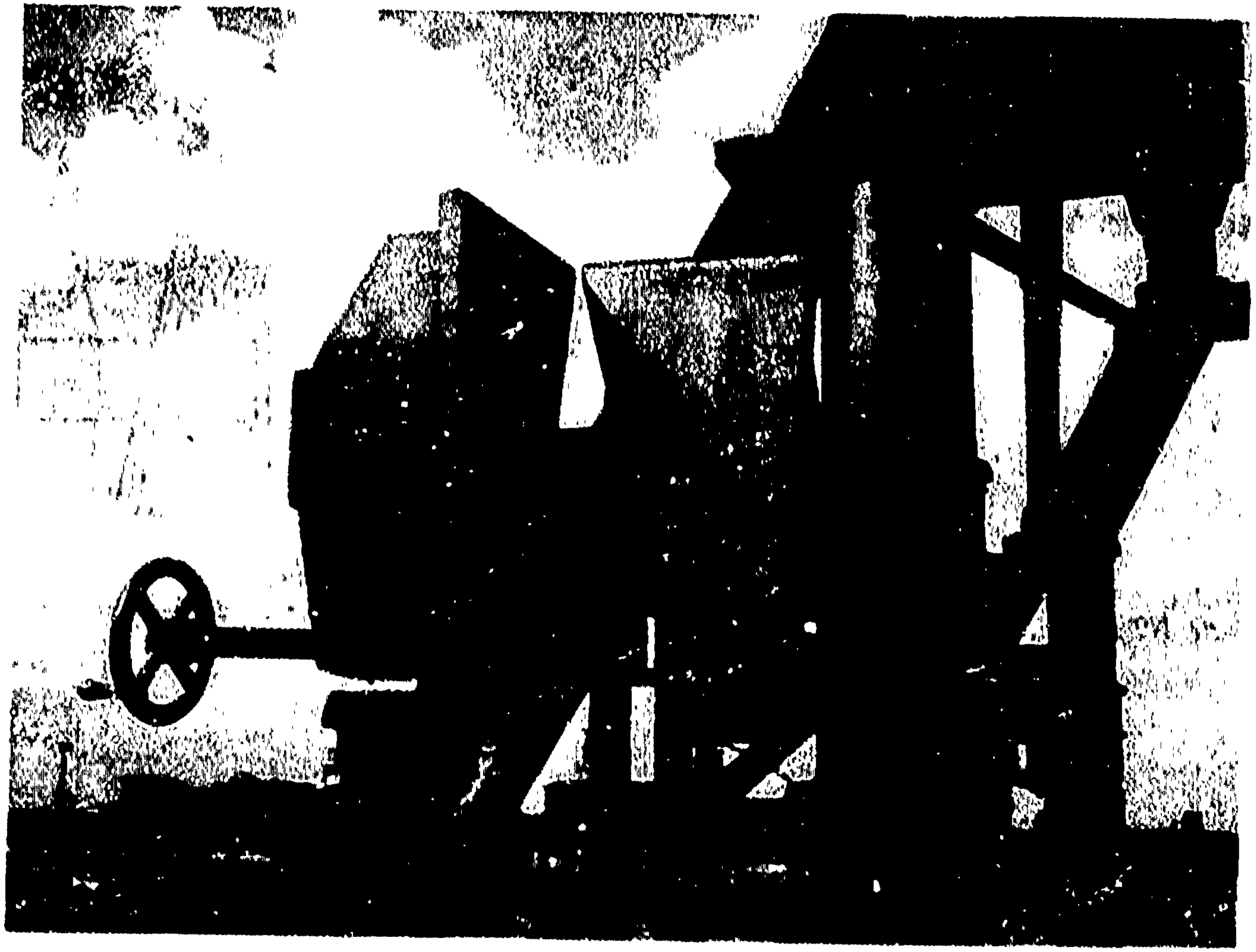


Figure 10. Close-up of one of the fine positioning assemblies. The assembly is in the "open" position.

Each of the guide assemblies is equipped with an operator's platform, shown in Figure 7. Without the platform, shorter operators may have some difficulty turning the adjusting screws, which are over five feet above deck level. Also, it is easier for the operator to see the twist locks on the MILVAN chassis when he is elevated slightly.

The guide device is held in or out of loading positioning by a simple latch, which can be seen in Figure 9. The latch is hinged to the assembly and drops into a slot on the supporting mast. This allows quick and positive control of the unit as it is pushed by the crew into and out of position.

When fully assembled, the hopper weighs a total of 33,000 pounds. The base weighs 18,000 pounds; the top, including bumpers, 15,000 pounds. When the hopper is disassembled, no piece weighs more than 4,000 pounds.

OPERATION WITHOUT THE TOP

As stated earlier, the primary functions of the hopper top are to arrest the swinging motions of a container and then guide the container down to the fine positioning devices. Conditions may permit use of the hopper without the top. For example, the sea state may be mild, so barge and ship motions would be small. Or the container handling crane may be equipped with taglines that eliminate container motions. If either of these conditions exists, it may be possible to dispense with the top of the hopper and use only the guide assembly to position the container on a truck. The main advantages of eliminating the top portion would be the reductions in the bulk of the hopper system and set up time. Since the hopper is to be used primarily in amphibious operations in unimproved ports and must, therefore, be transported via amphibious shipping, any reduction in shipping cube and assembly time would be advantageous.

With these points in mind, the hopper was designed to be used without the top. The top can be unbolted from the base and set aside. This leaves just the base with the guide assemblies exposed. Figure 11 is a photograph of base without the top.

TRUCK FERRYING TO HOPPER AT SEA

As shown in Figure 2, the trucks are brought from the beach to the hopper on a three-section pontoon causeway. Each section is 90 feet long and the total length of 270 feet provides enough room for six trucks. Warping tugs or LCM-6's were used to push the causeways to the hopper barge.

An empty causeway is connectioned to the other side of the hopper barge. This is the causeway on which the loaded trucks will return to the beach. The trucks drive under the hopper, are loaded, and proceed forward to the empty or forward causeway. Once all the trucks are loaded and on the forward causeway, it is disconnected and push ashore. This leaves an empty causeway at the hopper barge - i. e., the causeway on which the empty trucks arrived. So next the causeway of unloaded trucks will connect to the opposite side of the hopper barge. In this manner the trucks always drive forward to under the hopper, are loaded, and then proceed to the forward causeway.

At OSDOC II there were three causeways in the system: one receiving loaded trucks from the hopper barge, one from which the trucks are driving onto the hopper barge, and one at the beach. At the beach the loaded trucks are driven off the causeway and across the beach to the cargo dump. Once all the loaded trucks have debarked from the beached causeway, the next group of trucks to be loaded drive on for the trip back to the ship.

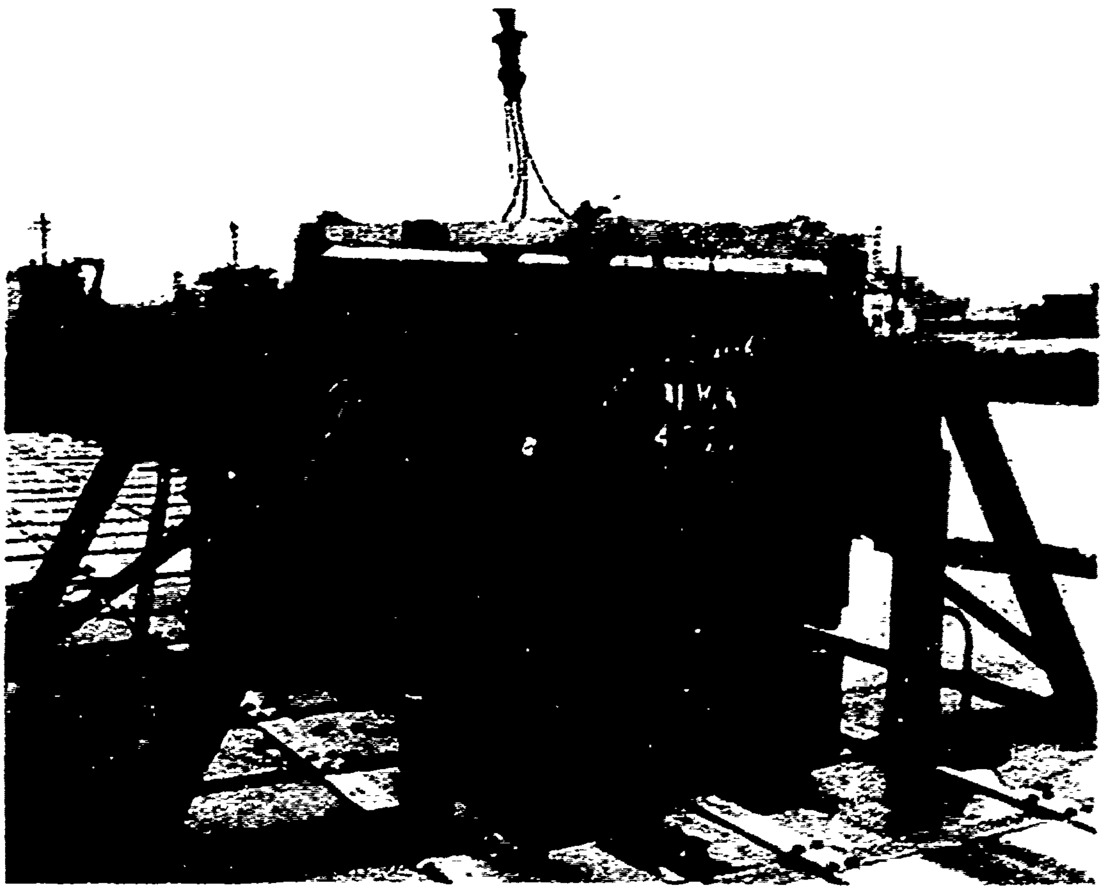


Figure 11. Hopper without the top. Fine positioning assemblies are in the "closed" position.

II. IMPACT TESTS OF THE HOPPER

INTRODUCTION

The bumpers were tested to determine their characteristics under loading to ensure that they met the design criteria. The impact tests were done at NCEL with the following objectives:

1. Measure the response of a bumper to impact loading.
2. Determine whether a standard 8'x8'x20' container, loaded to capacity, will be damaged if it strikes a bumper at a maximum horizontal velocity of three feet per second.

ARRANGEMENT OF TEST EQUIPMENT

The impact test consisted of swinging a large weight into one of the bumpers. Figure 12 shows how the test equipment was arranged. One bumper was bolted on the end of the rectangular hopper frame; some concrete weights were placed on the opposite end to prevent tipping of the frame and bumper upon impact. A truck crane with a 65-foot boom was parked behind the bumper. The crane was parked and the boom positioned so at rest the leading edge of the load was almost touching the bumper arm at the impact point. Impact was always at approximately the same location: an area about 5½ feet from the pivot point along the bumper arm.

The load was a 15-ton concrete anchor block suspended from a single lifting eye. To swing the load for a test run, a cable was tied to the lifting eye and the other end attached to a quick-release hook secured to a forklift. The forklift backed up a pre-determined distance and the quick-release hook unlocked, thereby allowing the load to swing into the bumper.

A Mitchell 16 high-speed camera was used to photograph two gridworks near the arm. One grid, of squares 2/10 of a foot on a side, was placed behind the arm. It was approximately 70" behind the bumper. This grid was photographed during most of the test runs since both the arm, impact point, and the load could be photographed simultaneously.

Two rods were welded to the free end of the arm and extended outward approximately four feet. These can be seen in Figure 12. A two-inch diameter disk was welded to the ends of the rods where they intersected. A second grid of one-inch squares was placed immediately behind the disk. The length of the rods exaggerated the motion of the arm and was particularly useful in measuring arm motions when the load was moving at slower velocities. It was not possible to photograph both grids simultaneously.

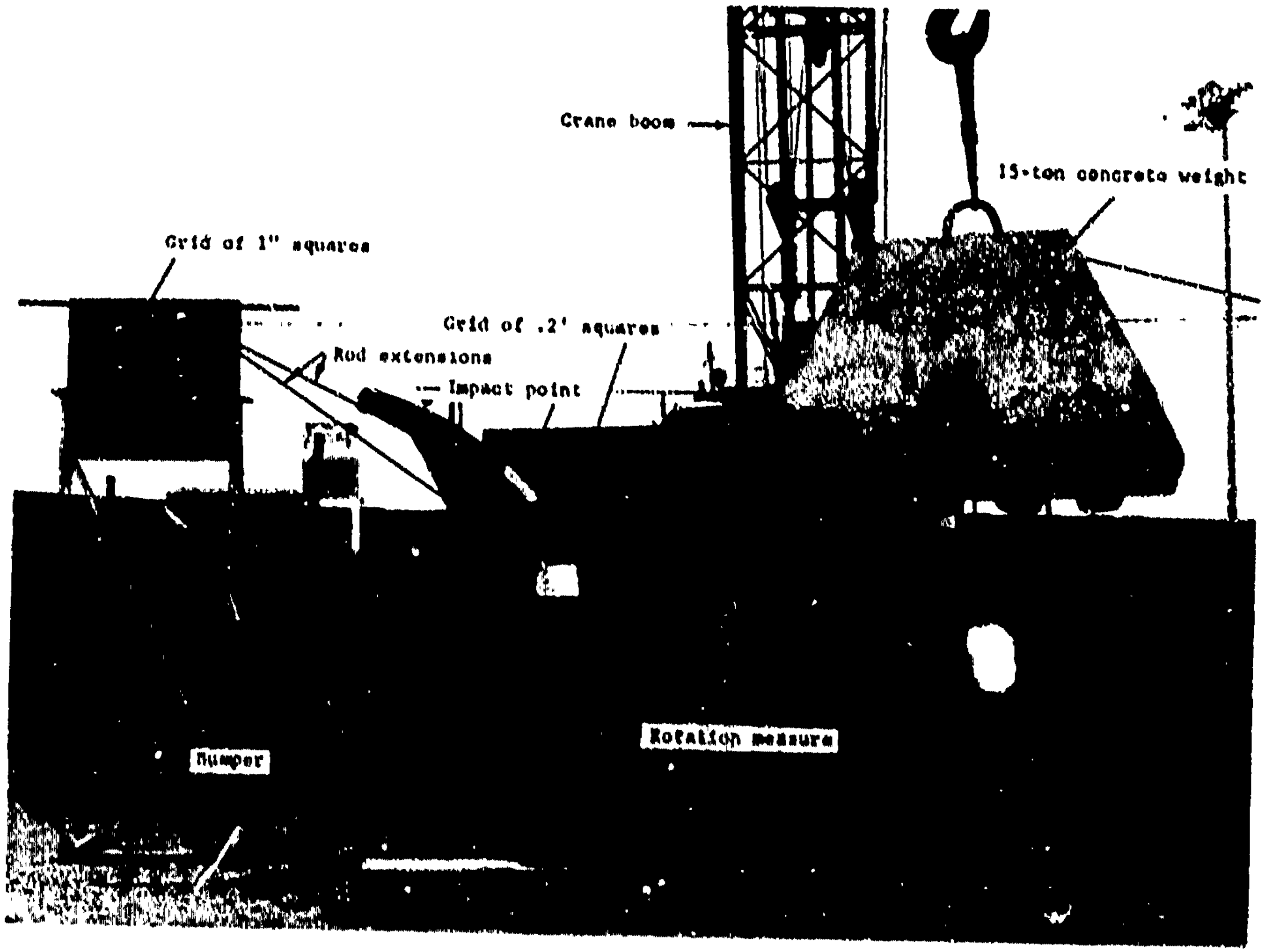


Figure 12. Test setup for impact tests.

A piece of plywood with radial lines every $2\frac{1}{2}^{\circ}$ was mounted on the arm at the pivot point (see Figure 12). A stationary rod was placed just in front of the plywood. This arrangement could be seen when the large grid was being photographed and permitted a quick and easy measure of the angular rotation of the arm during impact.

The high-speed camera was placed approximately 35 feet away from the bumper and operated at 112 frames a second. When photographing the large grid, the camera remained on a tripod on the ground. To photograph the small grid and disk/arm arrangement, it was placed on a seven-foot shipping container to give an almost head-on shot.

DATA REDUCTION

After the test, the film was processed and put on a Vangard Analyzer. The analyzer permits frame by frame viewing of the film. In addition, crosshairs can be superimposed over the viewing screen to permit measuring the movement of the load or any other object in the film, using the grid as the scale.

When viewing the analyzer, movement of the arm or load in front of the large grid was not a direct measurement since the grid was not immediately behind the arm and/or load. Thus, using the grid will give a measurement greater than actually experienced by the load or arm. Solving this problem requires nothing more than using similar triangles to calculate the simple linear relationship between actual and measured distance.

Time measurements were made by counting frames, assuming 1/112 second between frames. The rate of 112 frames per second is accurate to $\pm$ 2%.

In analyzing the film on the analyzer, an arbitrarily chosen reference point of displacement and time was used. In general, an easily recognizable spot on the striking weight was followed from the moment it first appeared on the film. The location of the spot at that moment was used as the reference point. Once the reference point was chosen, the following steps were used to take data from the film:

1. record the x, y coordinates of the reference point;
2. advance the film 14 frames (the equivalent of 1/8 of one second); and
3. move the x, y hairlines on the screen to the new location of the reference point and record the new coordinates.

These steps were repeated until impact of the weight and arm had taken place. Then, in addition, the motion of a point on the arm was also followed by recording its x, y coordinates at different times.

One of the easiest and clearest ways to view the capability of the bumper to attenuate the horizontal motions of a load is to compute the amount of energy absorbed during impact. The bumper and load is a system which possesses a certain amount of energy which is a function of the velocity of the concrete block just before impact. The way the test was set up, the block was at the bottom of its swing just slightly before it hit the bumper. Consequently, the total energy of the bumper/load system is equal to the kinetic energy of the load just before impact:

Total energy = K. E. of load just before impact =

energy absorbed during impact with bumper + kinetic energy of load after impact.

Letting

V_i = velocity of load at impact

V_s = velocity of load at separation from bumper arm

M = mass of load

E = energy absorbed during impact

$$\left(1/2\right) M V_i^2 = E + (1/2) M V_s^2$$

or

$$\left(\frac{V_s}{V_i}\right)^2 = 1 - E/((1/2) M V_i^2)$$

The ratio of $(V_s/V_i)^2$ is, therefore, a measure of effectiveness: It is the fraction of total energy dissipated in any one impact, i. e., the ratio of the kinetic energy of the load after impact to the kinetic (total system) energy before impact. This ratio will be used as a measure of system effectiveness in the following discussion.

OBSERVATIONS AND DISCUSSION

Test results are presented in terms of horizontal-displacement history of the striking weight, and the angular displacement history of the arm. The velocity of impact, V_i, was obtained by measuring the slope at the point of impact of the horizontal-displacement history curve of the striking weight. Impact velocities of 1, 2 and 3 feet per second were used. The velocity of separation, V_s, was obtained in the same manner.

V_i = 1 fps Runs (Figures 13 and 14)

There were three test runs at this velocity. Data fron one run was reduced. The weight was displaced initially 21 inches horizontally from its equilibrium position. A horizontal velocity of 1.13 fps (feet per second) was achieved at impact. The arm rotated 0.075 radians in about 0.75 seconds after impact. The weight separated from the arm at 1.9 seconds after impact with a horizontal velocity of 0.73 fps. The weight and arm stayed together during the whole period from impact to separation. There was no rebound (i. e., the arm didn't fling the load back), but the weight was observed sliding up and then down the arm. No noticeable physical damage of either the hopper arm or the concrete weight was observed. A ratio was obtained of the kinetic energy of the weight at separation to that at impact, i. e.,

$$\left[\frac{V_s}{V_i}\right]^2 = .42$$

V_i = 2 fps Runs (Figures 13 and 14)

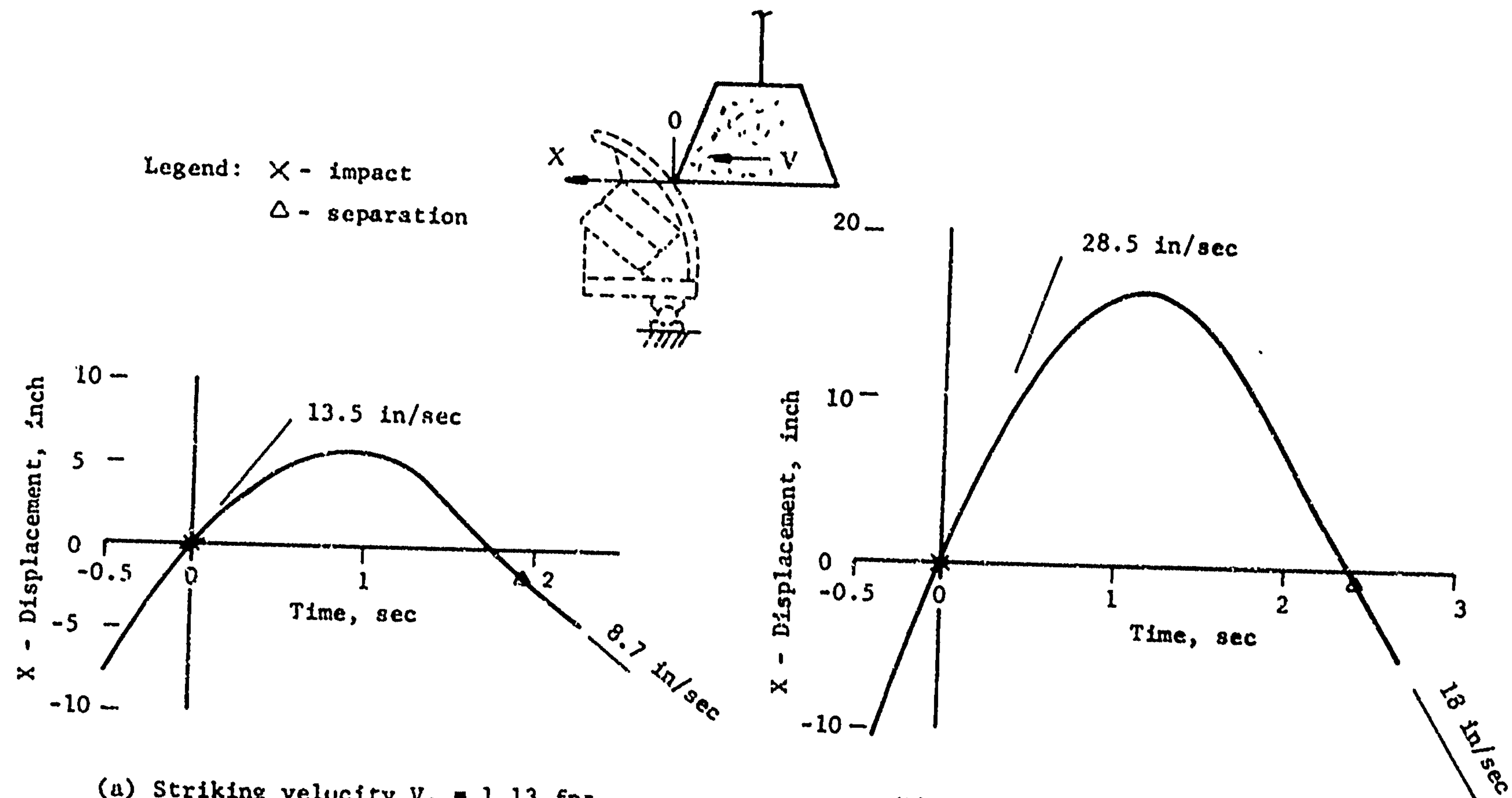
Three tests runs were conducted at this velocity. The weight was displaced 42 inches from its equilibrium position. Data reduced from one such test run showed an impact velocity V_i = 2.38 fps; a separation velocity V_s = 1.5 fps; a maximum arm rotation 0.15 radians, and a time duration of 2.4 seconds from impact to separation. Again, there was no rebound, but the load slid about 10" up the arm from the point of impact. No physical damage was observed on the load and arm. It is intereeting to note that the arm dwelled about 1/4 of a second during its recovery rotation as the load slid downward. The dwelling was believed to be a combined result of weight rotation and deflection characteristics of the shock absorbing mechanism (Figure 14). A ratio

$$\left[\frac{V_s}{V_i}\right]^2 = .40$$

was obtained.

Runs of V_i = 3 fps (Figures 15 and 16)

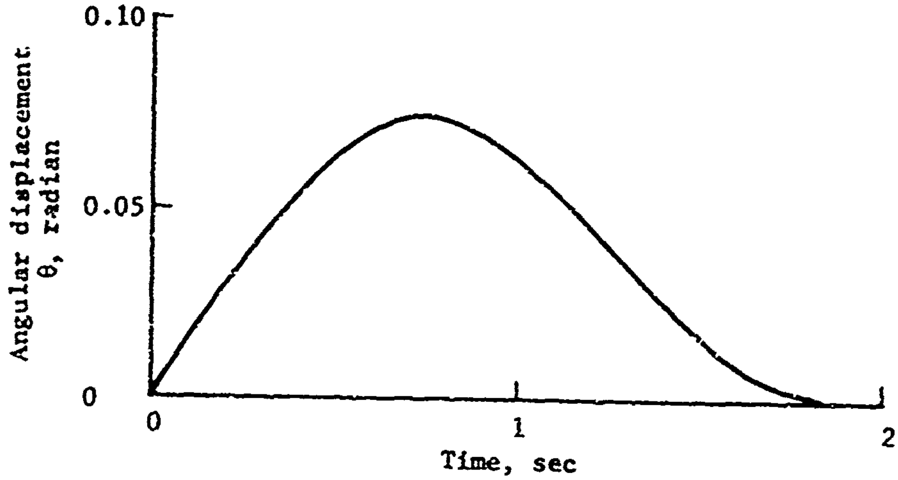
There were five tests runs at this impact velocity. The weight was displaced 62.5 inches from its equilibrium position before being released. Data reduced from one such run showed an actual impact velocity of V_i = 3.27 fps; a separation velocity of V_s = 2.23 fps; a maximum arm rotation of 0.22 radians; and a time duration of 2.85 seconds from impact to separation.



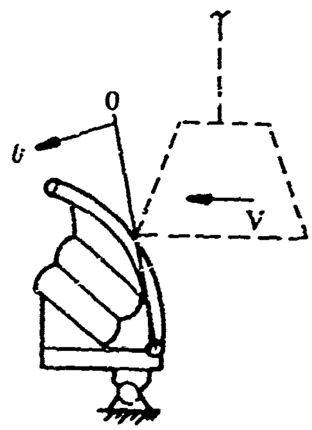
(a) Striking velocity $V_i = 1.13$ fps

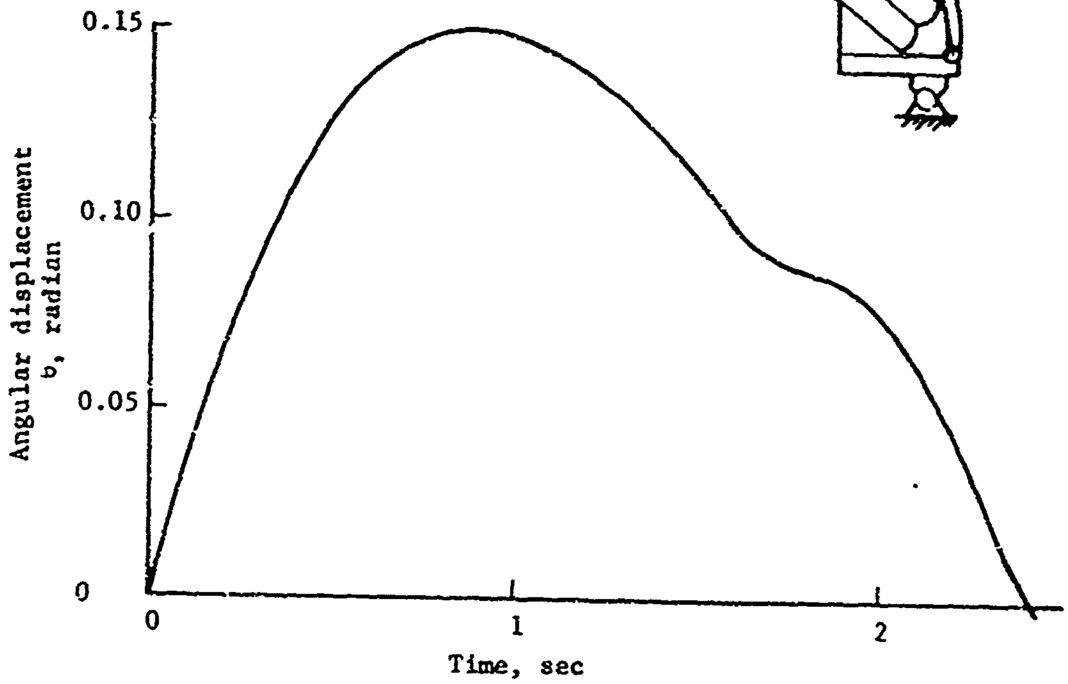
(b) Striking velocity $V_i = 2.38$ fps

Figure 13. Displacement history of striking weight.



(a) Striking velocity V_i = 1.13 fps





(b) Striking velocity V_i = 2.38 fps

Figure 14. Angular deflection history of hopper arm.

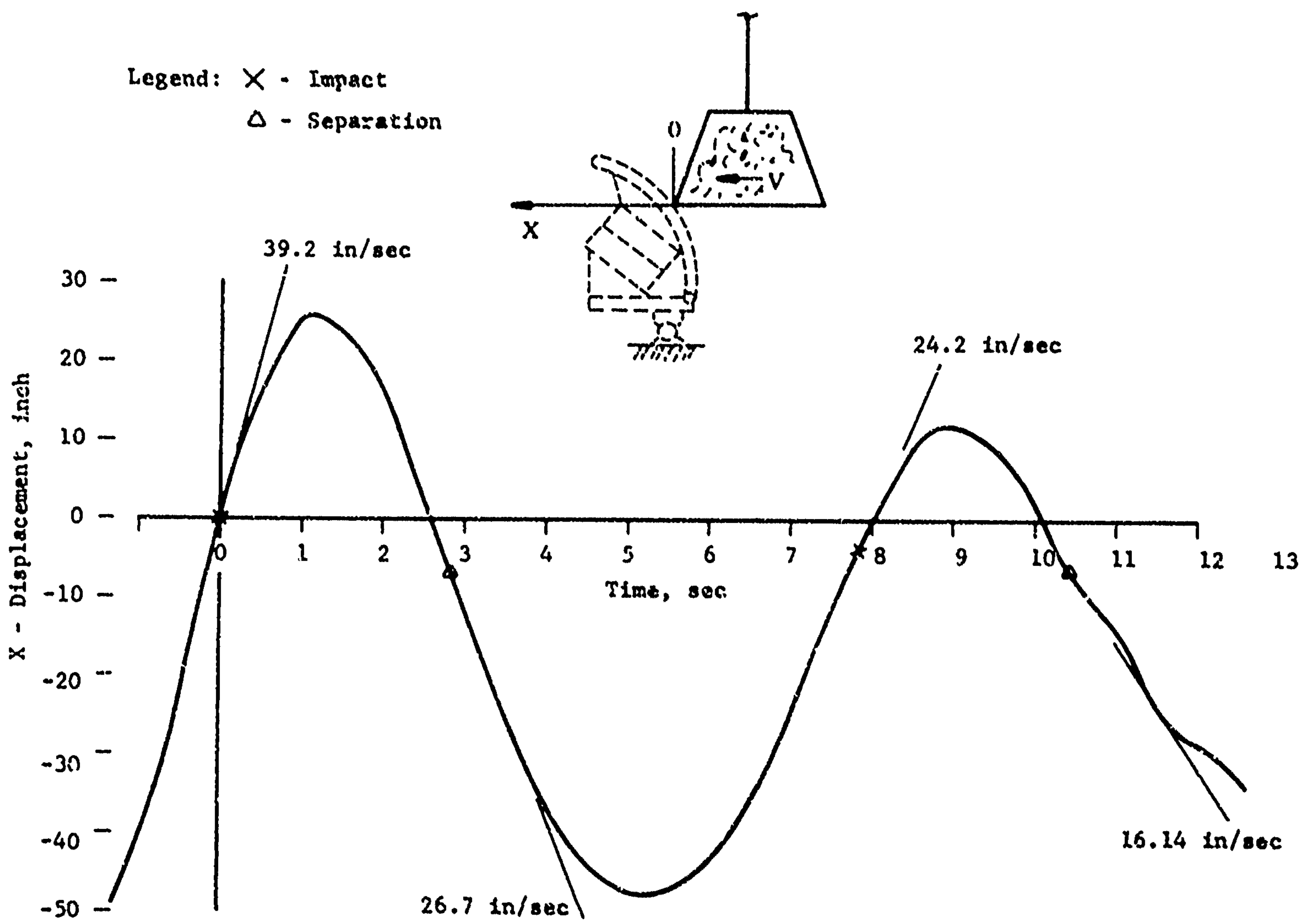


Figure 15. Displacement history of striking weight $V_i = 3.27$ fps.

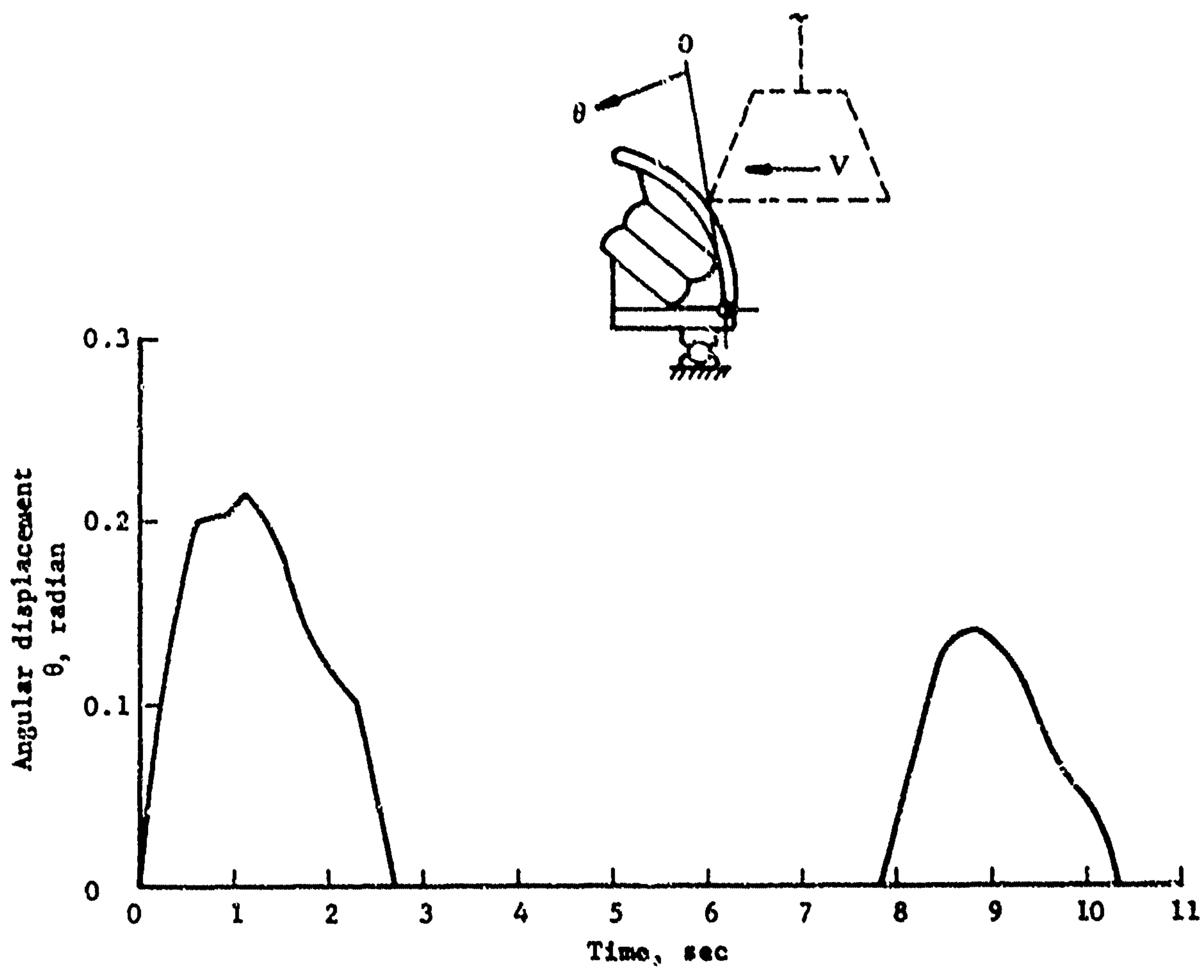


Figure 16. Angular deflection history of hopper arm - V_i = 3.27 fps.

There was no rebound, but sliding was observed. The weight slid upward along the arm an approximate total of 14" from the impact point. During this sliding, dwelling of the arm was observed during both its deflecting phase and its recovery phase. The dwelling lasted about 0.4 seconds during each phase (for a total dwelling time of 0.8 seconds). The load appeared to be always sliding along the arm at it pushed the latter. However, it would simultaneously slide and push to a point (about 5" above the impact point) where the arm would stop rotating and remain held in one position while the load continued to slide upward along the arm another nine inches or so and stop. The load remained stationary for an instant and then slid downward the nine inches, whereupon the arm would begin rotating back. There was always contact between the load and arm until the latter reached its neutral (unloaded) position. This action accounts for the dwelling of the arm and can be attributed in part to the location of the impact point and the geometry of the arm. An impact point lower on the arm, or an arm that is not curved, may not have allowed dwelling to occur.

A ratio of

$$\left[\frac{V_s}{V_i}\right]^2 = .46$$

was obtained.

In contrast to the previous cases, data from the second cycle were also recorded and reduced in this run. The data showed a second impact velocity $V_{i,2}$ = 2.20 fps and a separation velocity $V_{s,2}$ = 1.33 fps. $V_{i,2}$ at 2.20 fps is within 2% of $V_{s,1}$ which was measured to be 2.23 fps. A maximum arm rotation of 0.14 radian was measured and a time duration of 2.6 seconds from impact to separation. No rebound, but sliding was observed. No physical damage resulted in this second impact. A ratio

$$\left[\frac{V_{s,2}}{V_{i,2}}\right]^2 = .37$$

was obtained.

RESULTS OF IMPACT TESTS

The velocities of the striking weight reported were the velocities of a point "A" near the edge of the concrete block (Figure 17) but not those of the center of gravity of the concrete block.

In doing so, an error of no more than 3% is induced if a simple pendulum approximation is employed, since, referring to Figure 17b.

$$\dot{\theta} = \frac{V_{c.g.}}{63} = \left(\frac{V_A}{64.5}\right)\left(\frac{V_A - V_{c.g.}}{V_{c.g.}}\right) = \frac{64.5-63}{63} < 3\%$$

No more than 4% error is induced if a pendulum with two degrees of freedom approximation (Figure 17c) is used as the model, since

$$V_{c.g.} = 60\,\dot{\phi} + 3\,\dot{\theta}$$

$$V_A = 60\,\dot{\phi} + 5.15\,\dot{\theta}$$

$$\frac{V_A - V_{c.g.}}{V_{c.g.}} = \frac{2.15\,\dot{\theta}}{60\,\dot{\phi} + 3\,\dot{\theta}} = \frac{2.15\,\dot{\theta}}{60\,(.97\dot{\theta}) + 3\,\dot{\theta}} = \frac{2.15}{61.2} < 4\%$$

(As shown in Appendix A, the amplitude $\dot{\phi}$ in the fundamental mode is approximately 0.97 that of $\dot{\theta}$. Appendix A also presents a discussion of the estimates of error associated with equating the velocity of point A with that of the center of gravity of the weight.)

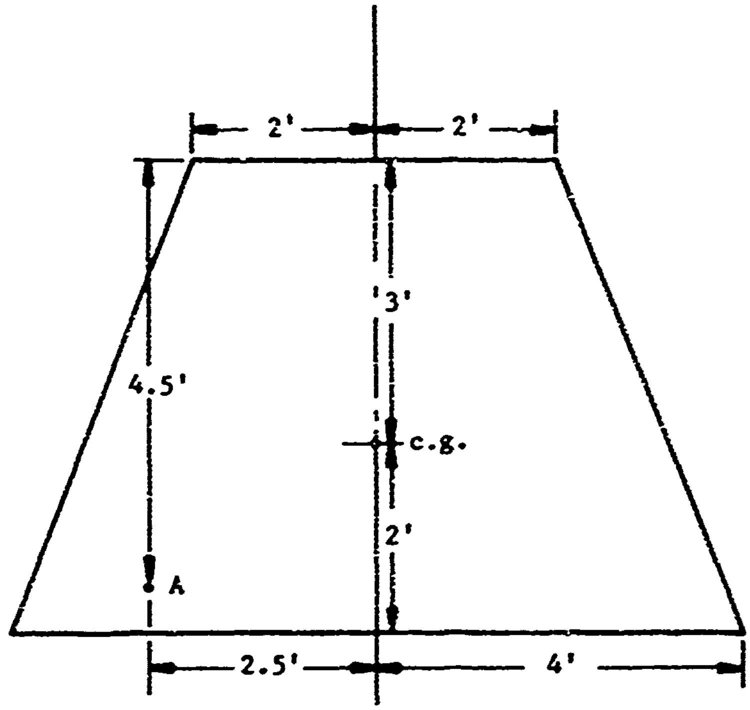
Slight rotation of the striking weight was evidenced by the difference in impact points of the first and second cycle for the 3 fps run. The second impact took place 0.2 second and 4 inches sooner than theoretical calculations indicated (cf. Figure 15). As shown in Figure 15, this rotation induced little change in the slope of the displacement history curve in the immediate neighborhood of the impact point.

Summary of Runs at 1, 2 and 3 fps

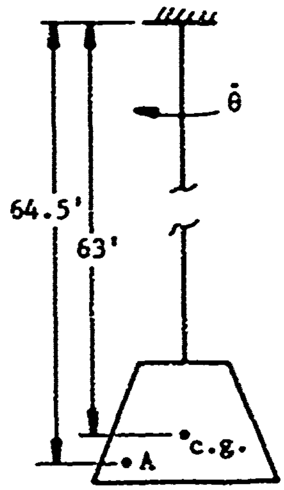
The runs with the 15 ton load are summarized below:

Run	$(V_s/V_i)^2$	V_s/V_i	Max Arm Def (Rad)
1 fps	.42	.65	.075
2 fps	.40	.63	.15
3 fps - 1st impact	.46	.68	.22
2rd impact	.37	.61	.14

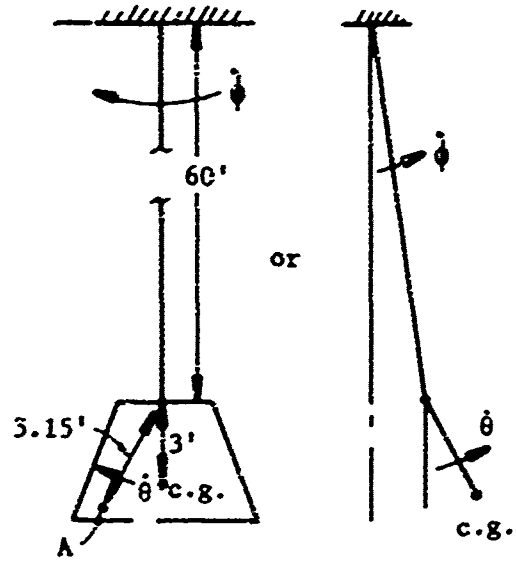
It can be seen that the ratios of V_s/V_i are all within 4% of their average. Consequently, as a rule of thumb, the separation velocity of the loads is about .64 of the impact velocity for the 15 ton concrete block.



(a) concrete weight



(b) simple pendulum approximation



(c) pendulum with 2-degrees of freedom

Figure 17. Specifications of weight and supporting cable.

Similarly, the square of (V_s/V_i) i. e., the ratio of kinetic energy of the block at separation to the kinetic energy at impact, is about .40. Thus, it appears that the bumper absorbs about 60% of the 15 ton load's kinetic energy regardless of the impact velocity (assuming that it strikes first at about 3 fps or less).

The above are approximations, of course, but are useful numbers when discussing the shock absorbing features of the bumper in general terms. It should be noted that they were measured from tests with a 15-ton load striking the bumper arm at the same place in every impact. Different size loads will undergo different motions. However, for loads in the neighborhood of 15 tons, the behavior exhibited by the bumper in the tests can serve us a good approximation.

Figure 18 shows a plot of the actual measured velocity of the corner of the load (point A) during the impact tests in which the initial striking velocity was 3.27 fps. Also, plotted in Figure 18 is the theoretical velocity of the center of gravity of the concrete block if it were allowed to swing back and forth as a simple pendulum starting from the initial condition. In other words, the measured velocity of point A shows what happened to the load hitting the bumper, while the theoretical curve shows what would have happened if there were no bumper.

Since the high speed camera was focused on the arm and impact point, the load could not be seen until it had traveled about 1/3 of the way to the arm. This is why some of the measured V_A curve is not plotted just before impact. An estimate was made of about where the measured curve should start in relation to the theoretical curve, assuming both started at time zero. It is important to note, however, that the differences in the peaks and valleys of the two curves are the most significant quantities. It can be seen that the velocities of the load are reduced considerably after two impacts with the bumper arm. Without the arm the load would still be swinging at over 3 fps; instead, it is swinging at less that 1 fps after only two impacts.

To get an overall estimate of the cushioning effect of the bumper, note that the area under the negative part of the measures velocity curves (the center portion) is 62% of that under the computed (theoretical curve).

Effect of the Cover Plate

The cover over the hole in the lower fixed plate of the bumper (see Figure 5) is provided to restrict the outward flow of air from the interior of the tires as they are compressed. The hole in the lower fixed plate is 1-3/4 feet in diameter and the cover provides a 5/32" gap around the perimeter through which the air can pass.

Due to limitations in time and crane availability, it was decided not to vary the gap width. However, some calculations were made* which

*Northrup Corporation, Electronics Division, Report NORT 72-95.

suggested that peak contact force between the bumper arm and container may be reduced somewhat if the gap were reduced from 5/32" to .05". A reduction in the impulse was also indicated.

Nevertheless, calculation of stresses in a full-loaded container striking the bumper arm show that the container is not over-stressed if the gap is 5/32". The calculations are discussed in the following sections. Consequently, the bumpers, as tested, are satisfactory and no changes in the gap width is necessary or worthwhile.

DETERMINATION OF FORCES ON BUMPER ARM

The data discussed to this point provide insight into how the bumper behaves as it is struck by a load. The next step is to determine: (1) the magnitude of the forces during impact and (2) what stresses would be induced in a standard van container by these forces. This entailed measuring the deflection/force curve of the bumper and relating it to the motions of the arm under loadings as seen on the film.

Calibration

Figure 19 shows the set-up for the static calibration of the hopper arm, and the raw data obtained. Figure 20 shows the moment-angular deflection relationships which were deduced (graphically) from the calibration data using a 1" = 1' scale. The calibration curve, presented as moment vs angular deflection curve, is shown in Figure 21. The curve shows a non-linear nature of the tires as they are compressed.

Force Calculation

With the angular deflections of the V_i = 3 fps test run (Figures 15 and 16) as the entering points, the corresponding moments were read from the hopper arm calibration curve (Figure 21).

Assuming that the force at impact consisted of a normal component, N, in a direction always normal to the hopper arm, and a frictional component, μN, in a direction always tangent to the hopper arm, (see Figure 22) it can be shown that:

$$N = \frac{M}{d_N \pm \mu d_{\mu N}} \tag{1}$$

where

μ - is the coefficient of friction between the concrete block and arm.

d_N and $d_{\mu N}$ are the moment arms of the forces N and μN, respectively.

M - is the moment read from the hopper arm calibration curve (Figure 21).

The sign in the denominator is determined by the direction of μN.

The table in Figure 22 lists the coordinates of the impact point, the direction angle, ϕ, of the normal to the hopper arm, the moment arms d_N and $d_{\mu N}$. All the quantities were obtained graphically using a 1" = 1' scale. Also listed is the computed values of $\mu d_{\mu N}$. Two values for μ were used: $\mu = .57$ for steel on steel, and $\mu = .47$ for aluminum on steel.

Table 1 and Table 2 present the values of N computed by using equation (1), and the values of the resultant R by

$$R = N\ (1+\mu^2)^{\frac{1}{2}} \tag{2}$$

and the direction of R by $\gamma = (90^\circ - \phi) \pm \tan^{-1}\mu$. (3)

A maximum value of R = 6,240 pounds with a nearly vertical direction was obtained. All the above were deduced from the data of the first cycle of the 3 fps test run. Those for the second cycle are shown in Figure 23 and Tables 3 and 4.

As can be seen, the magnitude, the direction, and the point of application of R varied during the period from impact to separation. Consequently, the induced stresses in the container also vary during the impact.

CALCULATION OF STRESSES IN THE CONTAINER

In the analysis of the stresses in a container striking the hopper arm it was assumed that the inertia force of the arm is small. Therefore, the system can be viewed as quasi-static; that is, the force imposed on the container by the arm is a function of only the deflection of and the position of the container on the arm. In other words, a container will "see" a series of static loads as it hits and slides along the arm. It is assumed that containers hitting the arm will hit at the same impact point or higher than that used in the tests with the 15-ton concrete block, and in addition, will generally follow the same path as the block up and down the arm.

Since the tests with the concrete block were practically a worst case situation - i. e., a relatively large mass hitting the bumper arm at greater than design velocity - it is unlikely that any container hitting the arm will be subjected to forces larger than those calculated in the previous section. This is particularly true of containers weighing less than the 15-ton block.

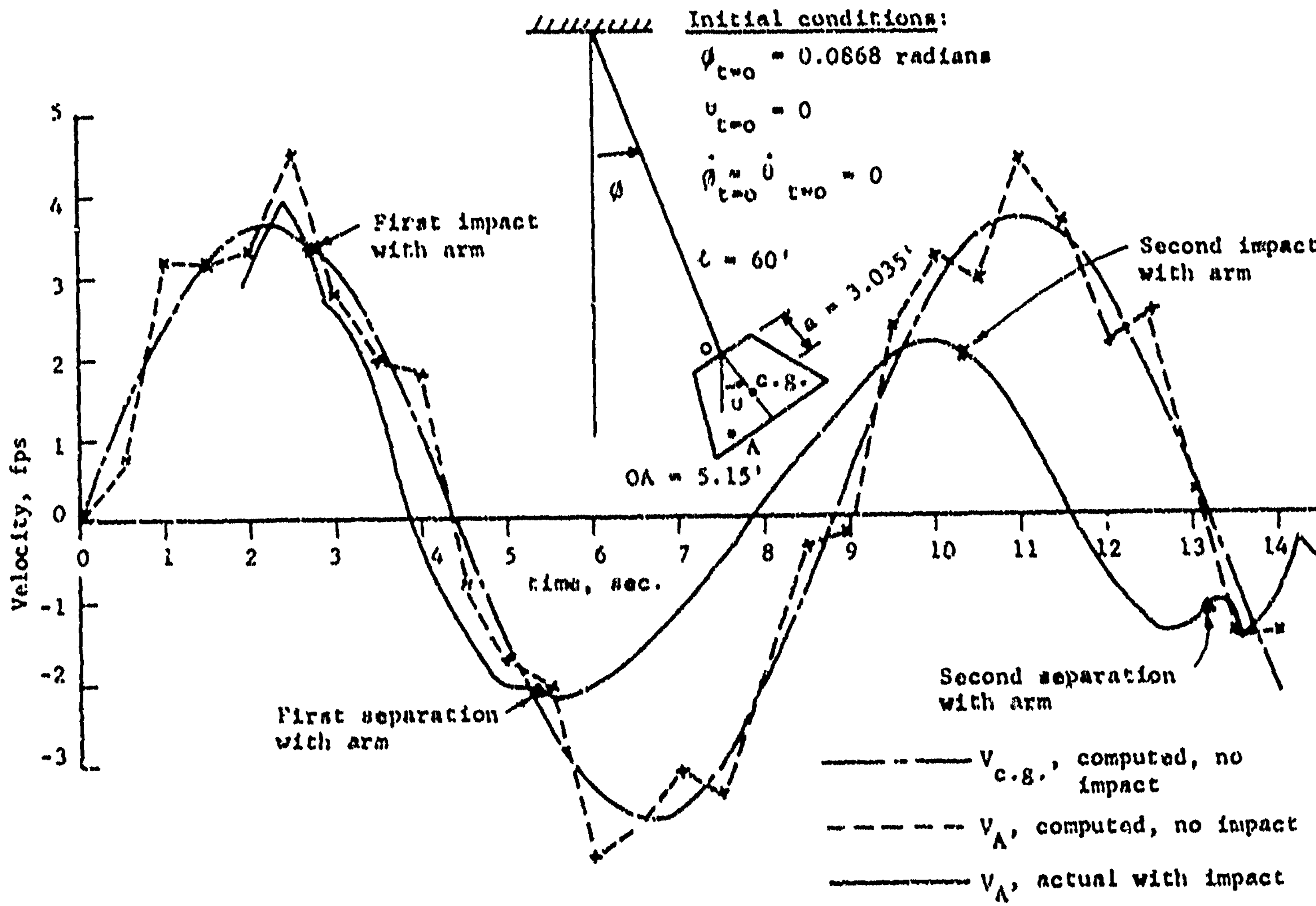
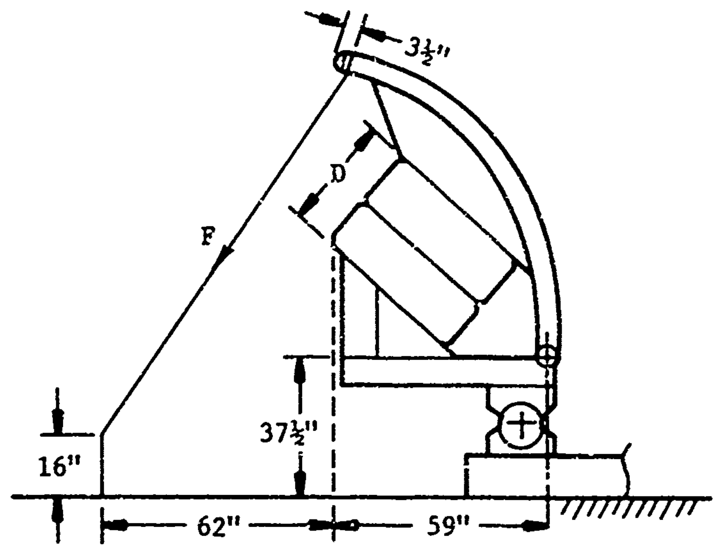
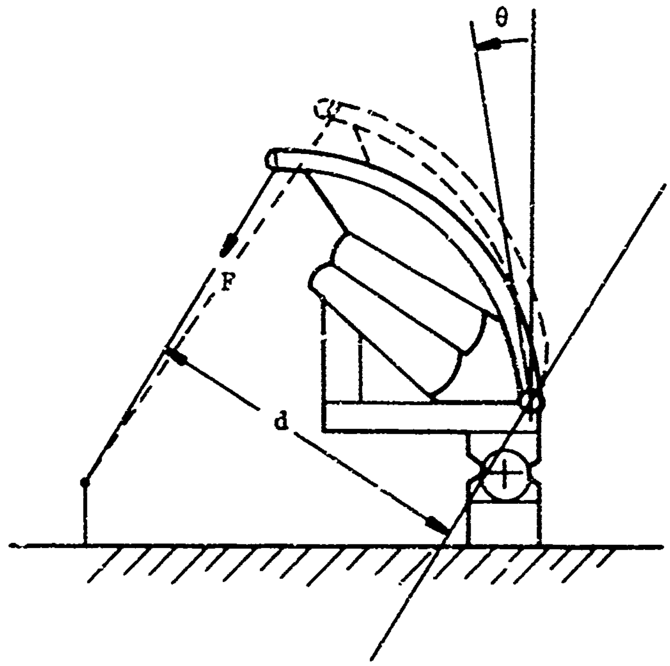


Figure 18. Comparison of velocity curves.



F, lbs	D, in
0	36
250	35-3/4
500	34-3/8
1,000	30
1,500	27
1,725	24-3/4
2,000	23
2,500	21-5/8
3,000	20-3/8
3,500	18-3/4
3,500	13-1/4

Figure 19. Setup for hopper arm calibration.



F, lbs	d, in	M = Fd, in-lb	θ, Radian
0	87.4	0	0
500	87.7	43,850	0.021
1,000	89.2	89,200	0.091
1,500	90.0	135,000	0.136
2,000	91.3	182,600	0.199
2,500	91.6	229,000	0.220
3,000	92.0	276,000	0.238
3,500	92.4	323,400	0.262
3,500	93.2	326,200	0.349

Figure 20. Data of hopper arm calibration curve.

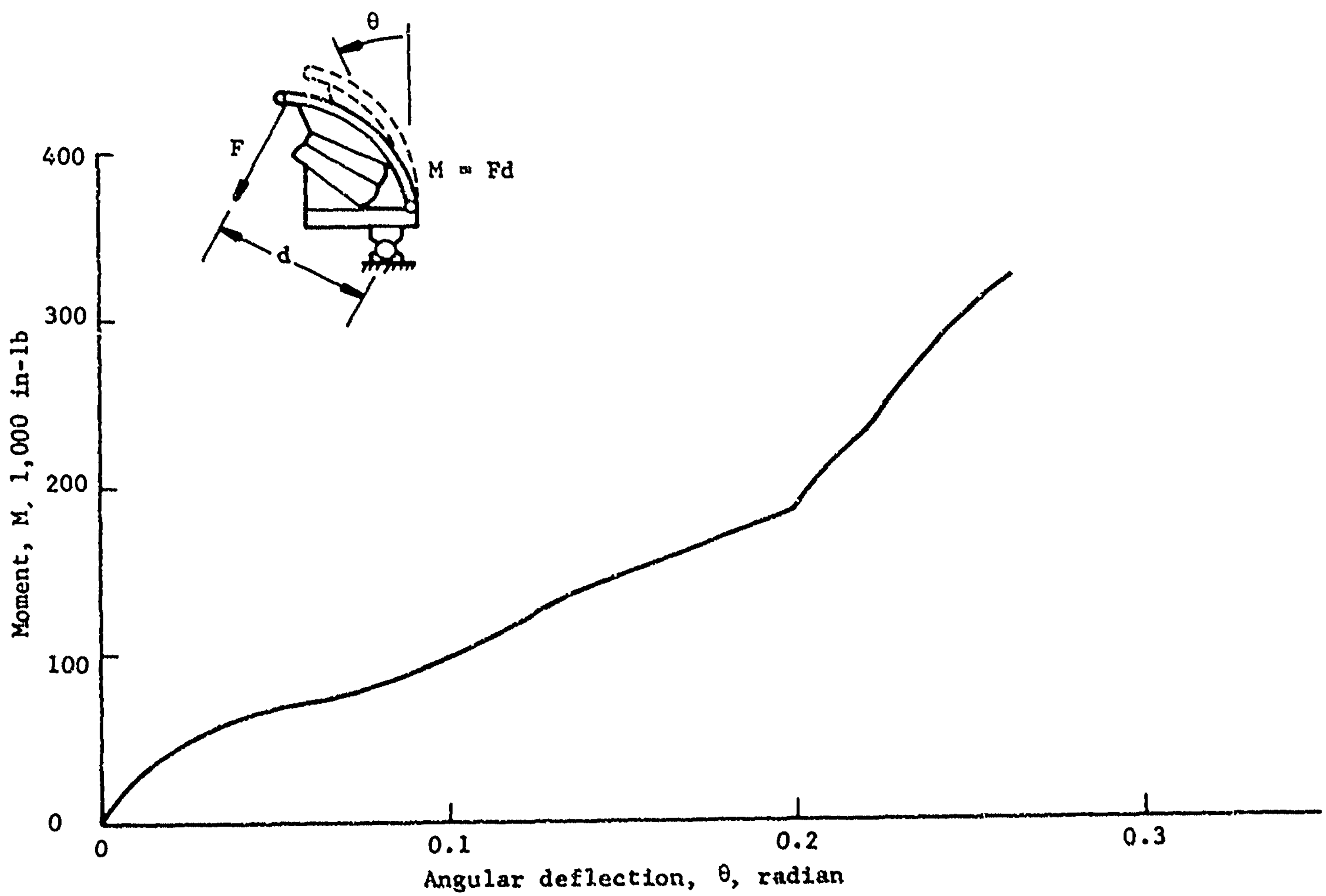
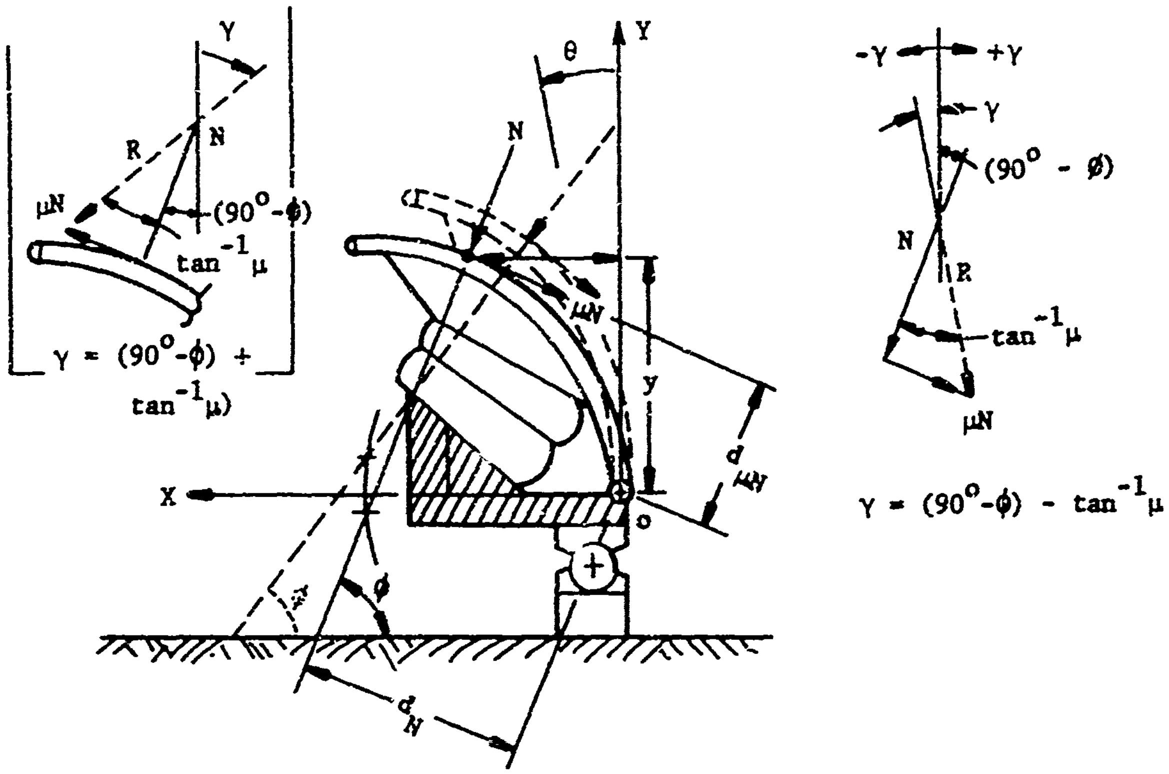


Figure 21. Hopper calibration curve.



Pt	Time Sec.	θ Radian	Contact Point x, in	Contact Point y, in	ϕ Degree	M, in-lb	d_N in	$d_{\mu N}$ in	$\mu d_{\mu N}$, in $\mu = .47$	$\mu d_{\mu N}$, in $\mu = .57$
0	0	0	20.75	55.50	47.1	0	59.6	34.3	16.10	19.55
1	0.20	0.089	27.80	65.00	53.9	87,500	60.7	35.8	16.85	20.40
2	0.45	0.175	37.20	63.00	58.9	163,000	61.1	36.4	17.10	20.80
3	0.70	0.201	39.25	63.80	64.0	190,000	63.2	39.8	18.70	22.70
4	0.95	0.206	40.25	64.25	64.9	200,000	63.8	40.8	19.20	23.30
5	1.20	0.215	39.80	63.75	64.4	220,000	63.4	40.0	18.80	22.80
6	1.45	0.192	38.50	65.00	63.4	177,500	63.5	40.5	19.05	23.10
7	1.70	0.148	33.70	66.20	61.2	142,500	63.5	40.5	19.05	23.10
8	1.95	0.135	32.90	65.20	58.3	132,500	62.1	38.0	17.85	21.70
9	2.20	0.119	29.60	65.00	55.5	117,000	61.3	36.5	17.15	20.80
10	2.45	0.065	24.70	63.50	50.9	73,000	59.2	33.5	15.75	19.10
11	2.70	-0.005	18.20	53.50	44.5	0	58.0	31.5	14.80	17.95

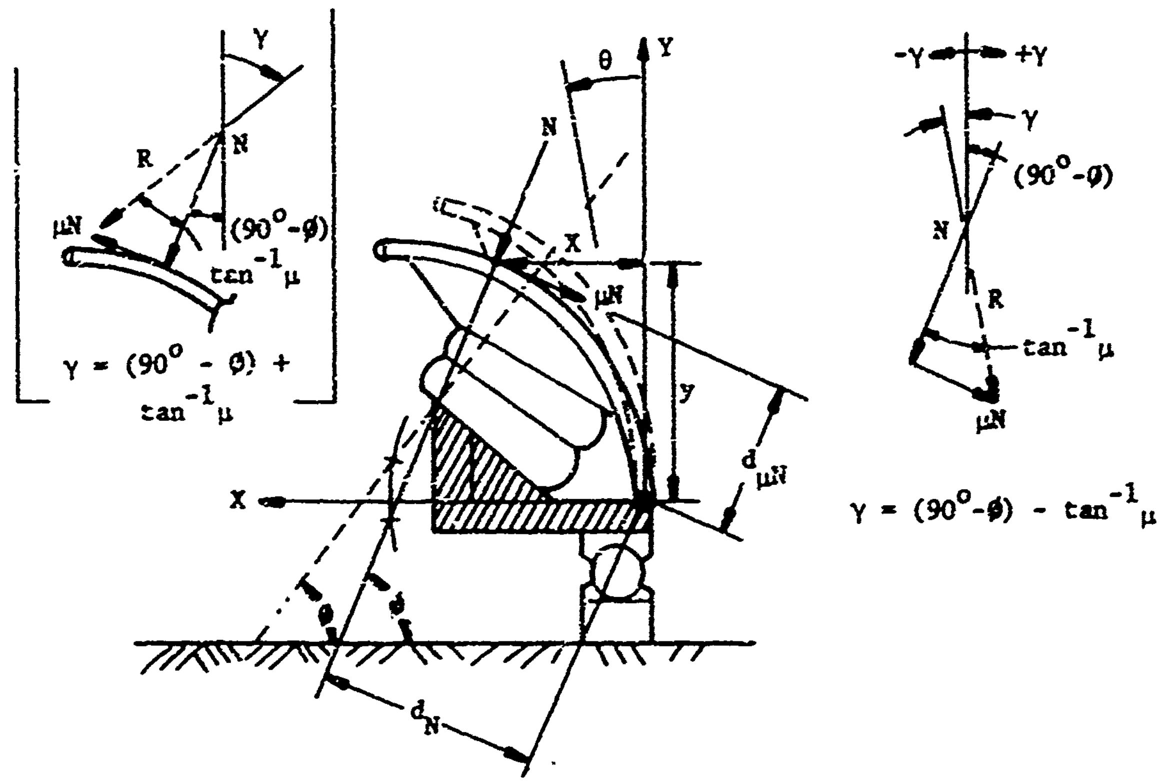
Figure 22. Container force, cycle 1.

Table 1. Values of Normal Force, First Impact, Upward Swing

Pt.	$d_N - \mu d_{\mu N}$		N, lbs		R, lbs		γ, degree	
	$\mu = .47$	$\mu = .57$	$\mu = .47$	$\mu = .57$	$\mu = .47$	$\mu = .57$	$\mu = .47$	$\mu = .57$
0	43.50	40.05	0	0	0	0	---	---
1	43.85	40.30	2,000	2,170	2,210	2,500	10.9	6.4
2	44.00	40.30	3,710	4,050	4,100	4,660	5.9	1.4
3	44.50	40.50	4,275	4,700	4,725	5,410	0.8	-3.7
4	44.60	40.50	4,490	4,940	4,970	5,700	-0.1	-4.6
5	44.60	40.60	4,930	5,420	5,450	6,240	0.4	-4.1
6	44.45	40.40	4,000	4,400	4,420	5,060	1.4	-3.1
7	44.45	40.40	3,210	3,530	3,550	4,060	3.6	-0.9
8	44.25	40.40	3,000	3,280	3,320	3,780	6.5	2.0
9	44.15	40.50	2,650	2,890	2,930	3,330	9.3	4.8
10	43.45	40.10	1,680	1,820	1,860	2,100	13.9	9.4
11	43.20	40.05	0	0	0	0	---	---

Table 2. Values of Normal Force, First Impact, Downward Swing

Pt.	$d_N + \mu d_{\mu N}$		N, lbs		R, lbs		Y, degree	
	$\mu = .47$	$\mu = .57$	$\mu = .47$	$\mu = .57$	$\mu = .47$	$\mu = .57$	$\mu = .47$	$\mu = .57$
0	75.70	79.15	0	0	0	0	----	----
1	77.55	81.10	1,130	1,080	1,250	1,245	61.3	65.8
2	78.20	81.90	2,080	2,000	2,300	2,300	56.3	60.8
3	81.90	85.90	2,320	2,210	2,570	2,550	51.2	55.7
4	83.00	87.10	2,410	2,300	2.670	2,650	50.3	54.8
5	82.20	86.20	2,680	2,550	2,960	2,940	50.8	55.3
6	81.55	86.60	2,180	2,050	2,410	2,360	51.8	56.3
7	81.55	86.60	1,750	1,645	1,935	1,900	54.0	58.5
8	79.95	83.30	1,660	1,580	1,835	1,820	56.9	61.4
9	78.45	82.10	1,490	1,425	1,650	1,640	59.7	64.2
10	74.95	78.30	974	932	1,075	1,075	64.3	68.8
11	72.80	75.95	0	0	0	0	----	----



Pt	Time Sec	θ Radian	Contact Point		φ Degree	M, in-lb	d_N in	$d_{\mu N}$ in	$\mu d_{\mu N}$, in	
			x, in	y, in					μ = .47	μ = .57
0	9.09	0	17.50	62.50	43.5	0	57.5	30.2	1.42	17.2
1	9.21	0.0262	20.50	63.50	45.5	47,500	58.5	32.2	15.1	18.3
2	9.46	0.0785	25.75	63.40	51.5	80,000	59.6	33.5	15.7	19.1
3	9.71	0.1188	29.20	63.30	54.5	116,000	60.4	34.5	16.2	19.7
4	9.96	0.1400	33.10	64.00	58.0	137,500	62.0	37.0	17.4	21.1
5	10.21	0.1310	33.50	65.09	58.5	129,000	62.5	38.0	17.8	21.7
6	10.46	0.1220	32.70	65.60	57.8	120,000	52.8	38.0	17.8	21.7
7	10.71	0.0960	31.00	66.70	56.1	93,000	62.8	38.5	18.1	21.9
8	10.96	0.0699	27.10	66.00	52.0	75,000	61.3	36.2	17.0	20.6
9	11.21	0.0524	25.00	65.00	50.2	68,000	60.4	34.8	16.3	19.8
10	11.46	0.0297	20.50	63.30	46.0	53,000	58.5	32.0	15.0	18.2
11	11.71	-0.0087	16.20	61.00	42.0	0	56.0	29.0	13.6	16.5

Figure 23. Container force, cycle 2.

Table 3. Values of Normal Force, Second Impact, Upward Swing

Pt	$d_N - \mu d_{\mu N}$		N, lbs		R, lbs		γ, degree	
	μ = .47	μ = .57	μ = .47	μ = .57	μ = .47	μ = .57	μ = .47	μ = .57
0	43.3	40.3	0	0	0	0	----	----
1	43.4	40.2	1,095	1,180	1,210	1,360	19.3	14.8
2	43.9	40.5	1,820	1,975	2,010	2,270	13.2	8.8
3	44.2	40.7	2,630	2,850	2,910	3,280	10.3	5.8
4	44.6	40.9	3,080	3,360	3,400	3,870	6.8	2.3
5	44.7	40.8	2,890	3,160	3,190	3,640	6.3	1.8
6	45.0	41.1	2,670	2,920	2,950	3,360	7.0	2.5
7	44.7	40.9	2,080	2,270	2,300	2,610	8.7	4.2
8	44.3	40.7	1,690	1,840	1,870	2,120	12.2	7.7
9	44.1	40.6	1,545	1,675	1,710	1,930	14.6	10.1
10	43.5	40.3	1,220	1,315	1,350	1,510	18.8	14.3
11	42.4	39.5	0	0	0	0	----	----

Table 4. Values of Normal Force, Second Impact, Downward Swing

Pt	$d_N + \mu d_{\mu N}$		N, lbs		R, lbs		Y, degree	
	$\mu = .47$	$\mu = .57$	$\mu = .47$	$\mu = .57$	$\mu = .47$	$\mu = .57$	$\mu = .47$	$\mu = .57$
0	71.7	74.7	0	0	0	0	----	----
1	73.6	76.8	645	619	713	711	69.7	76.2
2	75.3	78.7	1,060	1,015	1,170	1,170	63.7	68.2
3	76.6	80.1	1,510	1,450	1,670	1,670	60.7	65.2
4	79.4	83.1	1,730	1,655	1,910	1,905	57.2	51.7
5	80.3	84.2	1,610	1,530	1,780	1,760	56.7	61.2
6	80.6	84.5	1,490	1,420	1,650	1,635	57.4	61.9
7	80.9	84.7	1,150	1,100	1,270	1,265	59.1	63.6
8	78.3	81.9	958	917	1,060	1,055	62.6	67.1
9	76.7	80.2	887	848	970	975	65.0	69.5
10	73.5	76.7	721	692	797	796	69.2	73.7
11	69.6	72.5	0	0	0	0	----	----

Computer program "SOLID SAP" was employed for calculating the stresses in a container striking the hopper arm.* A model with 1,210 mass nodal points, 378 beam elements for the frame structure of the container, 884 membrane elements for the cover surfaces other than floor, and 288 plate elements for the floor of the container was used. Stress distributions in the container were calculated for three loading conditions:

1. "roof pick-up" (supporting the container from the four upper corner fittings) with the container loaded to 89,600 pounds, i. e., twice rated capacity;

2. a unit concentrated load of 1,000 pounds applied vertically to one end (Figure 24a); and

3. a unit concentrated load of 1,000 pounds applied horizontally on one end (Figure 24b).

The stresses caused by the unit loads were multiplied by the appropriate factor to give actual stress. The multiplication factors were determined by resolving the force of the bumper arm on the container into horizontal and vertical components. These stresses were added to the stresses caused by the floor load, using the principle of superposition and assuming elastic behavior of the structural members of the container.

The load case chosen - that is, the container strking one bumper in the center of an 8-foot side - is considered the worst of the most likely loading situations as far as impact forces are concerned. It is unlikely, for instance, that the container would strike only one bumper on the 20-foot side; instead, it would strike two bumpers, which would result in smaller impact forces.

Stresses in the immediate neighborhood of the load application point for two loading cases are given in Figure 25. The values given are the combined stresses in the beam elements caused by roof pick-up and impact with the bumper. Cases I and II were determined from the hopper tests for, respectively, the first and second impacts of the concrete block tests (discussed previously) were the first striking velocity was 3.27 fps. The peak stress values calculated are 12,980 psi in tension and 8,810 in compression, both on the first impact. (The forces used in each case are the maximums determined from the impact tests.) The yield strength of the container frame members is 36,000 psi, so it is evident that the members are not overstressed (particulary when it is remembered that for the sake of safety, the program "loads" the container to twice its actual weight capacity).

*Wilson, Edward, "SOLID SAP, A Static Analysis Program for Three Dimensional Solid Structures," University of California at Berkeley, UC SESM 71-19, March 1972 version.

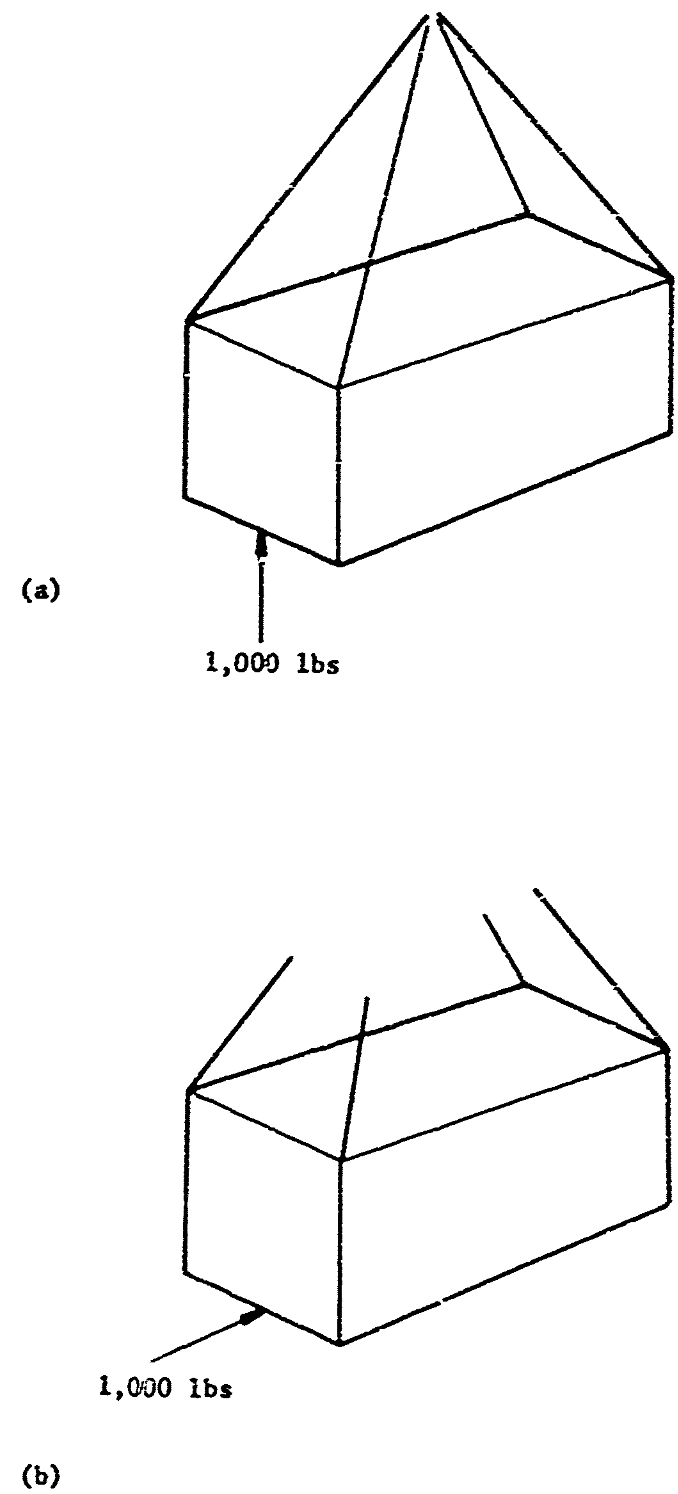


Figure 24. Load cases.

A cross-section of the beam used in the calculations is also shown in Figure 25. This is a representative beam; that is, it is typical of the members used as the end cross-member in a container. This particular member is from a Quick-Camp module, a container developed for the Seabees as a shelter/service unit compatible with container handling and transport equipment. The Quick-Camp container meets international regulations and as such it is at least as strong as any other shipping container. Details of container construction vary between manufacturers so under the same loading conditions another container will most likely have different values than those in Figure 25. However, considering the similarities between containers - they are more alike than unalike - there is little danger in assuming that the results given in Figure 25 would change only moderately at worst if another container were used as an example. Also, at the stress levels involved, even gross percentage differences between containers would be of little concern.

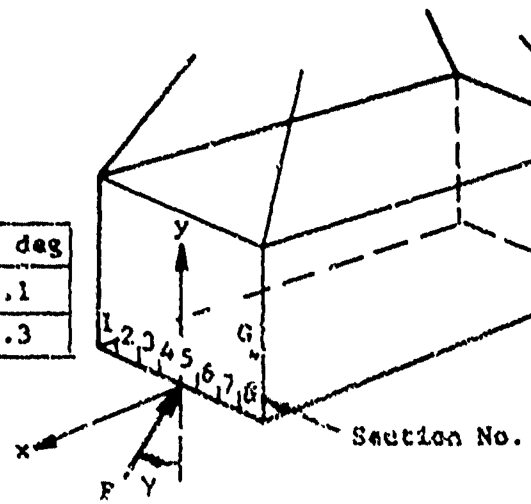
One point worth noting is the stress level in the neighborhood of point "G" (Figure 25). This point is in the middle of a cross-member about 40" from the end. At G, a bending stress of 35,600 psi is reached due to the roof pick-up alone. The effect of the hopper induced load on the stress at G is less than 1%.

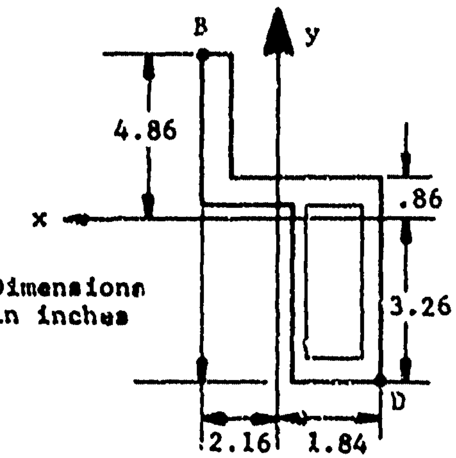
SUMMARY OF IMPACT TEST FINDINGS

The maximum stresses in the container due to impact are within acceptable limits. Based on a quasi-static analysis, the edge of the container which strikes the arm is not overstressed, even if relatively large forces are assumed. Using the largest impact force measured in the test, the maximum stress in the corner rail of the container is 12,980 psi (with the container loaded to twice its maximum capacity), which is well below the yield stress of 36,000 psi for steel. Usually a design stress of 20,000 psi is used for steel of the type used in a container. Consequently, it is concluded that a fully loaded container striking a bumper end-on at 3 fps or less will not be damaged.

Hopper induced load:

	F, lbs	γ, deg
I	6,240	-4.1
II	2,940	55.3





Load Case	Stress* psi	Section Number 1	2	3	4	5	6	7	8
I	σ_B	-500	-1,590	-3,220	10,770	12,980	-2,920	-1,320	-460
	σ_D	320	1,010	2,140	-7,330	-8,810	1,940	860	300
II	σ_B	-1,030	-1,360	-1,320	5,200	7,430	-1,020	-960	-1,000
	σ_D	770	700	150	-5,530	-7,010	-50	570	750

*Values shown are the combined stresses, i. e., the sum due to hopper induced loads and due to "roof pickup" static load (container loaded up to 89,600 lbs, i. e., twice its capacity).

Figure 25. Maximum stresses in container during impact.

III. OPE TIONAL TESTS OF THE HOPPER - OSDOC II

BACKGROUND

The container hopper was used in Offshore Discharge of Containership II (OSDOC II) in early October 1972 at Fort Story, Virginia. OSDOC II was a combined Army, Navy, and Marine Corps exercise done to test various means of unloading non-self-sustaining containerships in the open sea.* The hopper was a component in one of the unloading systems tested.

INSTALLATION OF THE HOPPER

The hopper was assembled and installed on the 7x15 barge by Amphibious Construction Battalion-TWO, Little Creek, Virginia. The hopper arrived at Little Creek disassembled, requiring that it be bolted together and the base plates welded to the pontoon deck. Once assembled, the two halves of the base were lifted onto the pontoon barge and placed on their respective base plates. The top was then placed onto the base and the entire unit bolted together. As noted in Figure 7, the bottom of each support let is bolted to the plates which are welded to the deck.

No unusual difficulty was encountered in the assembly and installation of the hopper. Before it is used again, however, the diameter of the bolt holes should be increased to provide greater tolerance for mating two pieces which are bolted together. Additionally, extra holes should be drilled in mating flanges so a spud wrench can be used to align the holes. These two improvements will make the assembly easier to accomplish.

A total of 96 man-hours were required in the assembly. Welders, steel workers and a medium size (20-ton) crane were needed to complete the job.

HOPPER OPERATIONS AT OSDOC II (10 October 1972)

The hopper was used on two successive days during OSDOC II. In addition, two weeks after OSDOC II, it was used in a test exercise at Little Creek, which simulated the OSDOC II tests. Each day's testing is discussed in detail in the following paragraphs.

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*A non-self-sustaining containership is a containership which does not have cranes on board.

The first day of operation was hampered by problems in mating one of the causeways to the 7x15 barge. The causeway with the trucks on it was connected to barge; the other causeway was not. Rather than disconnect the one causeway and return to the beach, 12 simulated loadings were done through the hopper.

The experiment consisted of driving the first truck off the causeway and into position under the hopper. The truck was a M-818 tractor with a MILVAN chassis. The large crane on the DeLong barge then removed a container, which weighed 10 tons, from a containership cell, lowered the container through the hopper and onto the chassis. The crew checked each corner of the container to ensure that the twist locks of the chassis could be locked, i. e., that the truck was loaded, then gave the signal for the crane operator to lift the container off the truck, through the hopper and return it to the ship's cell.

The spreader bar was never disconnected from the container. No actual locking of the container to the chassis took place, since it is a minor task which only requires the crew to rotate a handle a turn or so to secure the container.

Once the container was clear of the hopper, the truck backed up onto the causeway and the operation repeated. This ensured that the truck had to be driven under the hopper and positioned before the next loading. See Figure 26.

Two different truck drivers were used. One drove in the first six runs; the other in the remaining six. Neither had driven through the hopper before the tests.

Two crews were used to operate the hopper. For the first six runs, nine Navy personnel were used: one at each of the four hopper guides, one handling each of the four taglines on the container spreader bar, and one in charge. Seventeen Army personnel were used in the second six runs: two at each of the four fine positioning guides, two on each of the four taglines, and one in charge.

Both crews were familiar with the hopper function and how it operated, but neither had used it more than a few times before the tests.

Elapsed Times - First Day

Elapsed times were measured beginning when the crane began to lift the container out of the containership cell, ending when the container was in position, ready to be locked onto the MILVAN chassis. For the first (Navy) crew, these times were 5, 2, 6, 2, 2, and 2 minutes, for an average of 3.2 minutes. For the second (Army) crew, the times were 2, 4½, 4, 5½, 2 and 2 minutes for an average of 3.3 minutes.

In all but a few of the 12 trails the crane operator began lifting the container out of the cell shortly after the truck appeared to be in position. In a few instances the container was out of the cell and over the hopper before the truck was in final position.

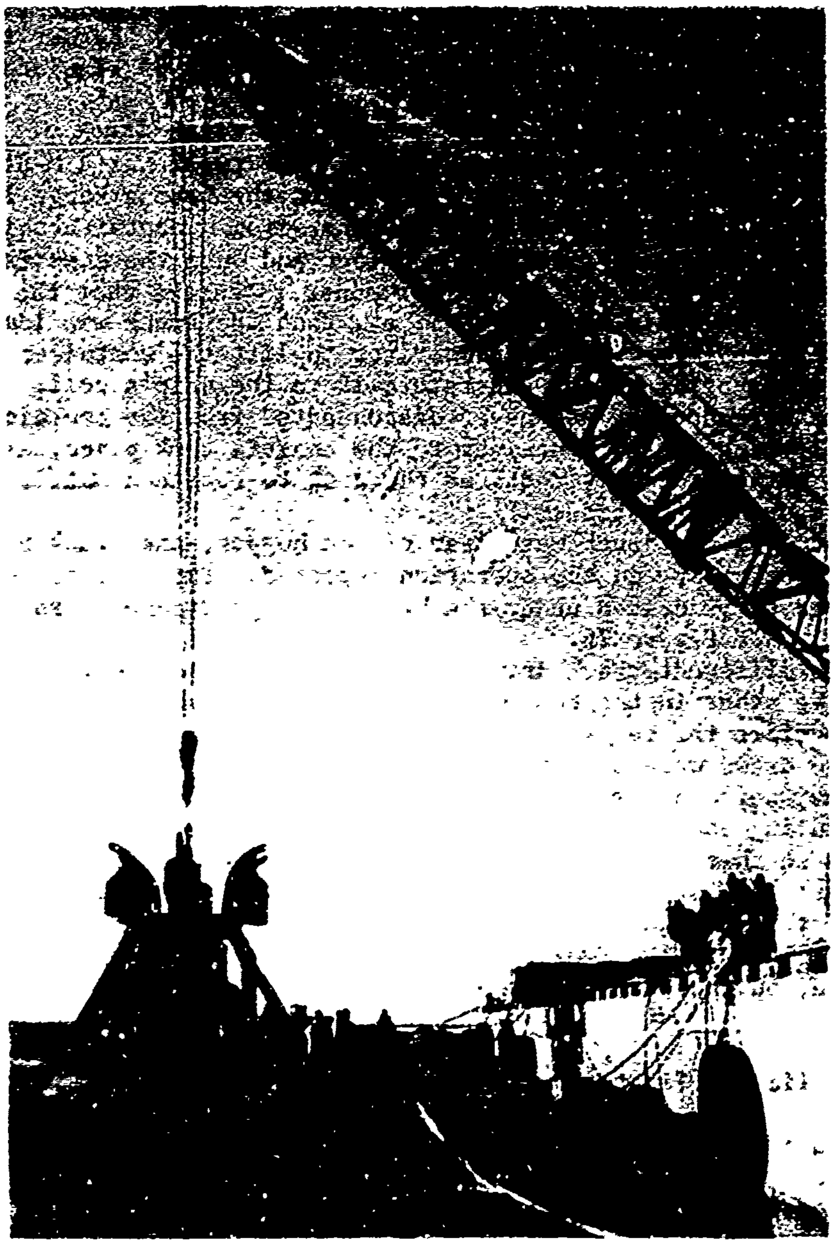

Figure 26. Loading operation during the first day of hopper operations during OSDOC II.

It must be noted that the timing of the six-minute run of the first crew did not begin until the container was over the hopper. This is in contrast to all other runs, in which the timining began as soon as the crane operator began lifting the container out of the ship. Additionally, there appeared to be some confusion during this run on the part of the deck crew. If the 6-minute time is eliminated as "dirt" in the data, the average time for the remaining five runs may be used, i. e., 2.6 minutes.

The overall average of all twelve runs was 3.25 minutes for the transfer of the container from the ship's cell, through the hopper, and onto the chassis.

The transfer of the container back to the cell - (the reverse of the loading cycle) took an average of two minutes. This time was measured on only six of the twelve runs: once for the Navy crew; five times for the Army crew.

Another way to view the operation is to consider only the times where the hopper itself was involved in a loading operation. This time is the "positioning time," and is independent of the time required for the crane to lift the container from the cell and swing it around to the hopper. Starting the measurement when the containers was first over the hopper (about 10-feet above it) and ending when the container was on the chassis, the elapsed time for the first crew averaged 2 minutes 3 seconds (4 trials); for the second crew, 2 minutes 24 seconds (6 trials).

It is important to remember that the average elapsed times given above are based on limited data. It is clear that the number of trials is too small to make statistically valid conclusions about the hopper loading times.

In addition, and perhaps most importantly, the trials were more of a practice session than a simulation of a sustained off-loading exercise. Tagline handling, for example, differed from run to run as the crews experimented with various handling techniques.

From an overall standpoint, therefore, it appears safest to classify the first days operation of the hopper as a trial and error period for all concerned - deck crew and crane operators.

Equipment Evaluation - First Day

The hopper was operated without difficulty on the first day. There were no problems in swinging the guide assemblies into position or turning the wheels. There were some minor things, which are noted below.

Taglines - Handling on First Day

Both crews had some difficulty in handling the taglines, which were attached to the corners of the spreader bar. This was particularly true of the second crew, which on two occasions had the taglines crossed up and tangled around some parts of the hopper. Further training with the hopper would at least alleviate this problem.

It should be noted in conjunction with tagline handling that the lifting beam on the crane was not equipped with a swivel. Consequently, it took more effort than desirable on the part of the deck crew to pull on the taglines to rotate the container. Since the 7x15 hopper barge is too small to allow handlers to move out and pull on the taglines with optimum force (see Figures 1 and 26), it is strongly recommended that a simple swivel be included in all future rigging for an operation of this type. On the second day of causeway operations a swivel was used to great advantage during the hopper operations.

Damage to the Hopper Guide Assembly Latch - First Day

As shown in Figure 9, the guide assembly rotates on a collar. A locking latch rotates with the assembly and can be dropped into one of two slots which locks the assembly in or out of loading position.

During one of the loading operations when the container was far down in the guides, just a few inches from the chassis, the crane operator pulled up on the container. The container was low enough in the guides that the lip on the lower edge of the door caught the lower edge of the fore-aft hinged guide. Similarly, the lip on the lower edge of the container at the other end caught the fore-aft guide at the opposite end of the hopper. Consequently, when the crane operator started lifting up on the container, the two guide assemblies were lifted along with it, sliding upward along their respective support legs. The latch was therefore lifted upward, out of the slot. Once clear of the slot, it fell inward so its non-hinged end was in contact with the support leg. When the crane operator lowered the container, the end of the latch dug into a ridge of the collar. The latch could not support the weight of the guide assembly and was bent.

Figure 27 shows one of the bent locking latches. The damage was not serious and hopper operations did not have to be suspended. Even with the handle bent, the latch would still work. The latches are equipped with a spring-loaded detent which will keep it in the locked position, during loading, or out of position as the guide assembly is being rotated. Some of the deck crew would push the latch inward past the point where the detent would engage, and this probably is the reason the latches fell inward.

The bent latches were easily straightened by pounding them with a sledge hammer. This was done on the following day just before operations with the hopper began.

To prevent damage to the latch in the future, a positive stopping device will be installed. It can be either a detent with a stronger spring, or a small pin in the slots to make it impossible to push the latch passed the point where it would point toward the support leg. Both solutions are simple and will be easy to do.

Figure 27. One of the bent locking latches.

Crew Size

The first day's operation indicated that the time and effort required to load a container through the hopper are not decreased by nearly doubling crew size from nine to seventeen. The 17-man crew was not any more effective than the nine-man crew, and it appears that the smaller crew size is all that is needed.

HOPPER OPERATIONS - 11 October 1972

In the second day of operation various trucks were driven off the causeway, loaded through the hopper, and driven forward to an empty causeway connected to the opposite side of the 7x15 barge. This was, of course, different from the previous day's operation, where only the one truck was used in the hopper loading tests.

The trucks from two causeway ferries were loaded through the hopper. They are discussed below.

For each of the two causeways, the crew size was the same. There was a total of nine: one at each of the four guide assemblies, one for each of the four taglines and one in charge. Both Army and Navy personnel were used.

First Causeway

The first causeway had six trucks on it. The first four were loaded using an automated spreader bar. Due to problems in the control system of the automated spreader bar, the remaining two trucks (as well as all the trucks on the second causeway) were loaded with the manual spreader bar. The malfunctioning of the automated spreader bar was in no way related to the fact that it was used in the hopper operation.

Table 5 presents data on the first causeway operations. The times are defined as follows:

Table 5. First Causeway Loading (11 October)

Container Wt (tons)/Number	Truck/Trailer	Elapsed Time to Position Truck	Elapsed Time to Load Truck
1. Empty/3766	M52/M127*	4:30	3:00
2. 10/4017**	M818/M127*	0:45	2:00
3. Empty/3643	M52/MILVAN chassis	0:30	1:45
4. 10/4010	M818/MILVAN chassis	1:30	1:45
5. 10/3729	M52/MILVAN chassis*	0:30	3:00
6. Empty/3648	M52/MILVAN chassis*	0:30	2:45
		avg = 1:22	2:23

NOTE: 1. Runs 1-4 done with automatic spreader bar; runs 5 and 6 done with manual spreader bar. 2. Read "minutes:seconds"

*Complete run with no delays due to spreader bar problems.

**Off center load.

Elapsed Time to Position Truck: Time beginning when the front bumper of the truck first passes under the hopper, ending when the truck is stopped in position to be loaded.

Elapsed Time to Load Truck: Time beginning when the crane operator begins to lower the container through the hopper (from about 10 feet above the bumper), ending when the spreader bar is disconnected from the container resting on the truck. This is the most significant time since it is the actual loading time at the hopper. Moreover, it should be noted that the truck could always be positioned in less time than it took the crane to swing over the ship, pick up a container, and swing back over the hopper. That is, crane cycle time and elapsed time to load the truck are critical and truck positioning is not.

Because of the delays in tyring to fix the automated spreader bar, the loading of the trucks through the hopper was not a sustained operation. In fact, operations were suspended for an hour as technicians attempted to fix the unit. Even runs No. 1 and 2 are suspect, since the spreader bar was beginning to fail during that time.

Runs 5 and 6 with the manual spreader went continuously. This can be considered a sustained operation. Total elapsed time to load the two MILVAN chassis was 7 minutes, which includes one minute delay between trucks. The average is 3 minutes 30 seconds per truck for two complete, sustained loading cycles.

Observations - First Causeway, Second Day

The same problems encountered in the previous day's operation occurred in the loading of the first causeway on the second day. Most notably, taglines were mishandled: sometimes they were left to hang free, thereby becoming tangled or caught on some part of the hopper. Again, lack of practice more than anything else was the problem.

After the first six trucks were loaded, the crane operator was interviewed. He stated that in his opinion taglines were not required at all in guiding the container into the hopper. The six hopper bumpers presented a large enough target for him to get the container into the hopper with no difficulty. Once in the hopper, of course, the taglines were clearly unnecessary.

The slight evidence there is indicates that the taglines are unnecessary to get the container into the hopper. In the third run (Table 5), taglines were not used and it can be seen that this is the shortest elapsed time. In the remaining runs the taglines were "used" in the sense that someone was pulling on them but according to the crane operator for all practical purposes he was doing the positioning by using the bumpers to center the container over the hopper.

Second Causeway, Second Day

The second causeway had five trucks on it, one of which was the Marine Corps' M123 tractor with two trailers. All the loadings were with the manual spreader bar. Table 6 is a data summary of the second causeway loading through the hopper. The data in Table 6 is presented in different form than Table 5. In Table 6, the elapsed time at various stages of the loading process are given. Time zero is when the bumper of the truck first passed under the hopper. The time the trailer was positioned (ready for loading) was considered the next event. Following is the time when the crane operator has begun to lower the container to the hopper. The final time is "spreader bar disconnected" which for the manual spreader is the time at which a deck crew member has pulled the rope to disengage the spreader from the container.

The delay between trucks, given in the last column of Table 6, is the difference in time between when the spreader bar is disconnected and time zero for the following truck.

Adding the elapsed times for each run to the delay between trucks gives total time, including crane cycle time, to load the five trucks with the six containers. The total is 34 minutes, 40 seconds or an average of 5 minutes, 46 seconds per container. Average delay between trucks is 38 seconds.

The average of the differences between the "time container began lowering" and "time spreader bar disconnected" is 3 minutes, 22 seconds. In other words, actual loading time through the hopper - disregarding crane cycle time and positioning of the truck - is 3 minutes, 22 seconds.

Observations - Second Causeway, Second Day

The taglines became tangled again on three of the trials, and it was evident that some of the crew members were still learning. However, the crew was coordinating the operation of the fine positioning guides with greater efficiency.

Comparing the time differences between "time began to lower container" and "disconnect container" of Tables 5 and 6, it can be seen that the trucks of the first causeway were loaded in consistently faster times than those of the second. This is particularly true of the MILVAN chassis times, where, for the first causeways, four chassis were loaded in an average time of 2 minutes 19 seconds, with none longer than 3 minutes; yet, for the second causeway the same average was 8 minutes 51 seconds for two chassis. This is most likely explained as a difference in crew familiarity with the equipment. For example, for the first truck off the second causeway, the man directing the truck had the driver stop nearly 3 feet short of the loading position, suggesting some lack of familiarity with the equipment.

Nevertheless, some of the loadings of the M127 flatbeds were accomplished in relatively short times. These were performed without too much difficulty, although taglines were mishandled occasionally.

Table 6. Second Causeway Loading Through the Hopper - 11 Oct 1972

Truck/Trailer	Container Wt/Number	Time When Trailer Positioned	Time When Crane Began Lowering Container	Time When Spreader Disconnected	Delay Between Trucks
1. M52/MILVAN chassis	5 T/3662	00:40	4:35	9:40	00:40
2. M52/MILVAN chassis	Empty/3749	00:50	2:20	8:50	01:00
3. M52/M127	5 T/3611	01:00	1:10	2:10	00:40
4. M52/M127	Empty/3645	00:10	2:10	4:10	00:30
5. M123 with tandem M127s					
1. First trailer	Empty/3638	00:30	1:00	3:15	
2. Second trailer	Empty/3787	00:38	----	2:45	01:00

NOTE:

1. Read "minutes:seconds"

2. All runs with manual spreader bar.

3. Timing began when the bumper of the truck tractor was first under the hopper (time zero).

4. Actual average loading time for the first five trailers is 3:22. This is the average of the differences between "Time When Spreader Disconnected" and "Time When Crane Begain Lowering Container."

The tandem trailer rig easily negotiated the causeway and had no problem driving through the hopper.

Overall, there were no problems in the operation of the hopper mechanisms. All components functioned satisfactorily during both causeway loadings.

Comparison of MILVAN Chassis and M127 Loading Times - Second Day

When loading the flatbed, all the crew had to do was ensure there was no overhang of the container once it was on the bed. They used the guide assemblies but manipulated them very little. In fact, the flatbed loads were essentially a straight through operation with no positioning of the container other than to have the fine positioning guides in position as the container was lowered.

On the other hand, the MILVAN chassis has the four twist locks on which the container must squarely rest. The room for error in placement is very small, on the order of 1/4". Not suprisingly, then, the fastest of all loadings was on a M127; it took 1 minute. Yet two of the fastest loadings (which were on the first causeway) were MILVAN chassis, which were loaded in 1 minute 45 seconds each. On the other hand, two of the longest loading times were with the MIVLAN chassis: 5 minutes 5 seconds and 6 minutes 30 seconds for the two chassis on the second causeway. As mentioned above, most of the problem here was due to crew inexperience. Considering that the four chassis on the first causeway were loaded in an average time of 2 minutes 19 seconds, with no time exceeding three minutes, it seems logical to conclude that something other than the fact a chassis was being loaded caused the longer times on the second causeway. The weather was no different and the containers were actually lighter (assuming that container weight is a factor), so lack of crew expertise appears to be the most appropriate explanation.

Using the times of the first causeway, the average loading time for the four chassis is 2 minutes 19 seconds; using the two trouble-filled runs of the second causeway, the average increases to 4 minutes 28 seconds. Thus, in either case - ignoring the extra long chassis loadings or not - the flatbeds were loaded in less than average time. Using what are considered representative data, however, the difference between the average loading times is only 16 seconds. Admittedly the quantity of data is limited, but it at least suggests what is possible when using the hopper. (For post-OSDOC II tests of considerably more trials, MILVAN chassis loadings averaged less than two minutes. These tests are discussed later in the report.)

COMMENTS OF THE CREW AT OSDOC II

It was the opinion of the crew members interviewed that the trucks - specifically the MILVAN chassis - could not be loaded without the hopper. Most mentioned that wind forces on the container as well as barge motions would make it extremely difficult - probably impossible - to use a crane to place a container on a chassis. Tests during OSDOC I in December 1970 substantiate these statements.*

Concerning the design and operation of the hopper, the crew had few comments. None found the hopper difficult to operate. One crew chief recommended that something more positive than the orange lines on the deck are needed to stop the truck in the loading position. This suggestion was heeded in the post-OSDOC II tests and proved to be worthwhile.

CRANE OPERATORS' COMMENTS AT OSDOC II

The crane operators had favorable comments on the hopper. They found it easy to use the six bumpers to orient the container for lowering the container to the truck. As stated earlier, one operator mentioned that he thought taglines were unnecessary to guide the container over the hopper. In fact, in one of the fastest of all the loadings during the two days at sea taglines were not used.

Another possible use of the hopper top was offered by one crane operator. He suggested that the hopper top be place over the containership cell to guide the spreader bar or retrograde containers into the cell. It was his opinion that this arrangement would be considerably more efficient than a crew on the ship pulling on taglines to maneuver the spreader so it can be lowered into the cell. With minor additions to the hopper top, this proposal could be carried out. It would be a relatively easy task to add short legs to the hopper top so it could be quickly transferred from one cell to another.

PENDULATION OF CONTAINERS AT OSDOC II

Because of the calm seas, the lack of wind, and the skill of the crane operstor, the container did not pendulate fore than a few feet in any direction. Consequently, the containers were never moving fast enough to hit the bumpers with significant force and the bumpers were therefore only lightly loaded. However, at sea and in the post-OSDOC II tests, the crane operators would sometimes lower the container quickly and it would strike a bumper fast enough to compress the tires a foot or

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*See, for example, "After Action Report: Evaluation of Off-Shore Discharge of Containerships, 5-9 Dec 1970," U. S. Army Transportation Center and Fort Eustis, Virginia, pages C-1 and C-2, where it is stated that "The practicality of positioning a container onto a chassis when either the lifting device, chassis, or both are influenced by uncontrolled motion is inconceivable."

so. Because the containers were not pendulating significantly, the bumpers were relied upon more as alignment devices than as energy absorbers. Nevertheless, they did deflect small amounts, which is more desirable than having the containers hit a rigid structure.

DAMAGE TO CONTAINERS

No damage occurred to any container lowered through the hopper. Paint on some corner fittings was scraped off, but this was not significant.

EFFECTS OF SEA STATE AND WEATHER ON HOPPER OPERATIONS

Barge motions at sea during the two days testing were mild. The first day (10 October), swells of four feet in height were recorded; on the second day, 2 feet. Consequently, there was some motion of the barge.

On a number of occasions on the second day, the container would be within half a foot of the trailer and it was noticed that the container was relatively stationary while the trailer was moving up and down with the 7x15 barge, sometimes making a contact with the container. In addition, the barge would move back and forth. It is this kind of motion which makes it extremely difficult if not impossible to use a crane to put the container on the MILVAN chassis without some assistance from the hopper. Once in the hopper, the container was restrained and the loading of a trailer was accomplished as if there were no motions at all.

Wind velocities never exceeded 17 knots during the loading operations at sea. The wind had no effect on the containers once they were confined by the hopper and very little, if any, effect on the containers swinging freely from the crane. Weather during the two days the hopper was used at sea was mild.

EFFECT OF CONTAINER WEIGHT ON HOPPER OPERATIONS

The containers lowered through the hopper were either empty or loaded to 5 or 10 tons gross. Some of the fastest loading times were with the 10-ton containers, suggesting that container weight has no influence on t' : speed of hopper operations. In addition, the hopper crew could not tell if the container was loaded or not as they manipulated the fine positioning guides. In sum, the weight of the container had no discernible influence on the speed and ease of hopper operations.

EFFECT OF SPREADER BAR TYPE ON HOPPER OPERATION

Three different spreader bars were used in the hopper loadings: two at OSDOC II and one in the post-OSDOC II tests (discussed in the following section). One was fully automatic and the other two were manually operated. As far as the operation of the hopper is concerned, there are no differences in the spreader bars.

Fine positioning of the container with guides did not vary with spreader bar type and, of course, the bumpers performed the same.

OVERALL EVALUATION OF HOPPER OPERATIONS DURING OSDOC II

The hopper was used without problems and no significant changes to it are necessary. From an overall standpoint the operation of the hopper was a success. The M127 flatbed trailers were loaded in as little as one minute and MILVAN chassis in 1 minute 45 seconds.

However, the hopper was not used as much as planned. The two crews operated the hopper a total of twelve times each: six times the first day and six times the second day. In other words, the hopper was not used enough on a consistent basis, which makes it difficult to draw any worthwhile conclusions about cycle times, equipment durability, and learning curves.

Given this situation, it was decided that more hopper tests should be done after OSDOC II. It was impossible, of course, to test it at sea with the containership, DeLong barge, and barge crane. But the arrangement of the equipment and the loading conditions could be realistically duplicated in a harbor with no large commitment of manpower and equipment.

IV. POST-OSDOC II HOPPER TESTS

GENERAL DESCRIPTION

The post-OSDOC II hopper tests took place at Amphibious Construction Battalion-TWO, Little Creek, Virginia, approximately two weeks after the completion of OSDOC II. A Navy crawler crane, parked on a dock was used to lower a container through the hopper onto a M52/MILVAN chassis. The hopper was still mounted on the 7x15 barge. Figure 28 is a photograph of the test setup. The container was empty.

The test procedure was the same as the first day's testing at sea. Starting from the far edge of the 7x15 (the extreme left of Figure 28) the truck was driven under the hopper. The crane then swung the container 90° - from over the dock to over the hopper- and lowered it through the hopper. Once the container was on the trailer so it could be secured with the twist locks, the deck crew rotated the guide assemblies to the open position and the crane operator lifted the container up and out of the hopper and swung it back over the dock. The truck was backed out of the hopper to the start position and the operation repeated.

The truck was loaded 25 times through the hopper with the hopper top in place. The top was removed and 25 loadings were done without the top, just using the fine positioning guides. For basis of comparison, 18 runs with the hopper were also done.

CREW

Usually there were seven SEABEES in the crew, but sometimes only five were available. There was one truck driver, a crane operator, and either three of four in the deck crew. If there were only three in the deck crew, the truck driver would help operate the hopper after he had the truck in position. There was never more than one man to a corner in the loading operation.

The tests took two days. Probably a total of ten to twelve men took part at one time or another. However, only one crane operator was involved; he ran the crane for every loading throughout the two days.

POSITIONING OF THE TRUCK

As mentioned in an earlier section, two orange lines were painted on the deck to mark where the front wheels of an M52 truck tractor should be for loading a MILVAN chassis. To make this stopping technique even more positive, a piece of lumber was placed on one of the orange lines to stop the truck. The arrangement is shown in Figure 29.

Using the lumber to stop the truck was very effective. Moreover, it was small enough that one man could easily place it on the orange line with no loss of time.

POST-OSDOC II TESTS WITH THE HOPPER TOP

The following times were measured for the 25 runs with the hopper top:

<u>Time Zero</u>: Clock starts when front bumper of M52 first passes under hopper.

<u>Time Truck in Position</u>: Time at which the truck is stopped, ready to load.

<u>Time Container Strikes Bumper</u>: Time at which the container first strikes any of the six bumpers.

<u>Time in Guides</u>: Time at which the lower edge of container is even with the upper edge of the fine positioning guides.

<u>Time Container on Truck</u>: Time at which all four lower corners of the container are in position, ready to be locked onto the MILVAN chassis.

<u>Time Container Clear</u>: Time at which the container has been lifted from the truck and is no longer over the hopper.

All of the above are elapsed times, beginning at "time zero."

Time to Position the Truck - Tests With the Top

The time required to position the truck (beginning of course, at time zero), averaged 24 seconds. The mode was approximately 15 seconds with some runs as short as 10 seconds.

Two of the runs were over a minute. In both cases, the driver came in crooked and the trailer wheels climbed up on the guide rails. Ignoring these two trials, both of which are anomalous, the average time to position the truck is 19 seconds.

In all runs, one of the crew, standing near where the truck should stop, gave directions with hand signals to the driver as he drove the truck under the hopper. The signalman also gave directions on when to stop, in addition to using the piece of wood as a wheel stop.

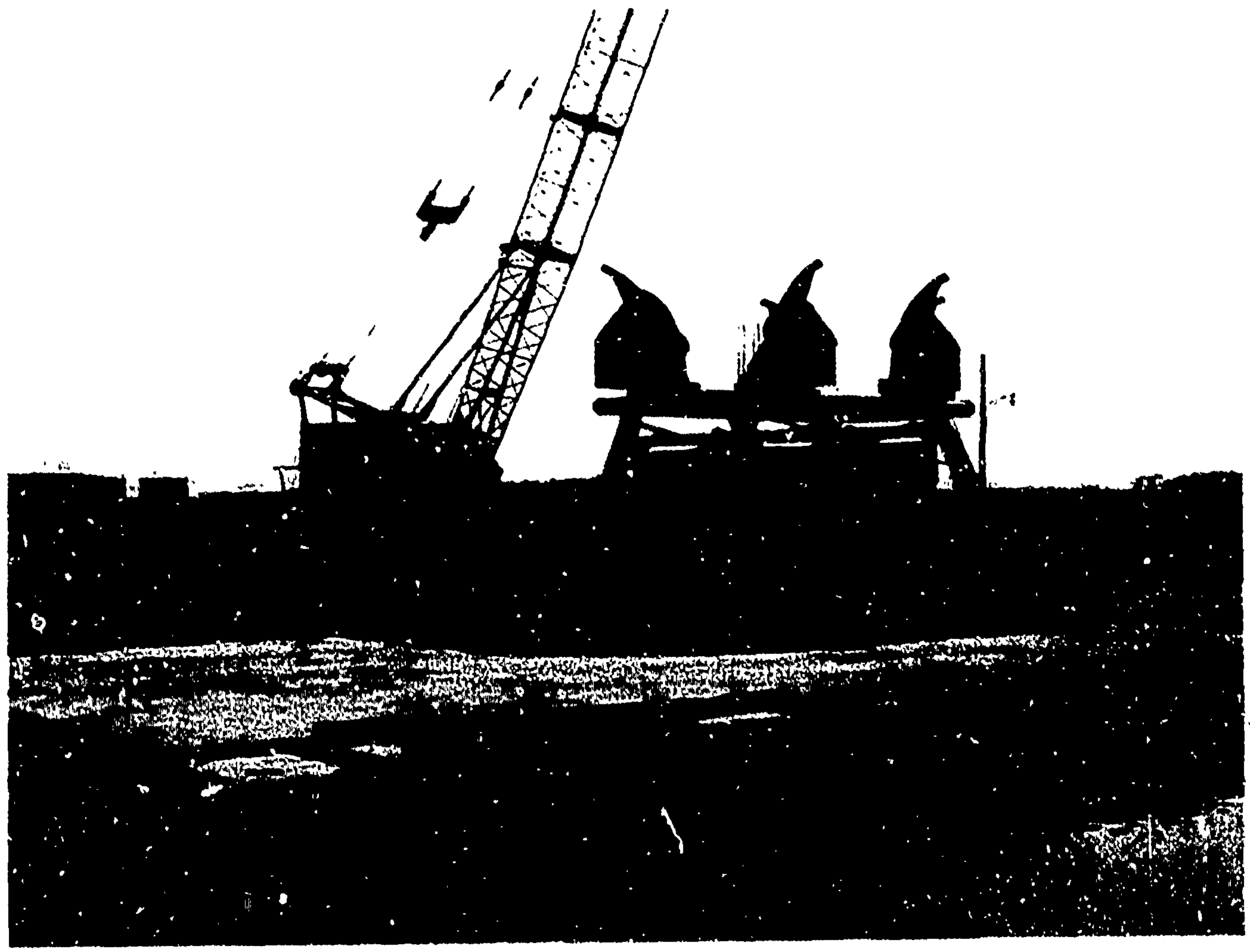

Figure 28. Test setup for post-OSDOC II tests.

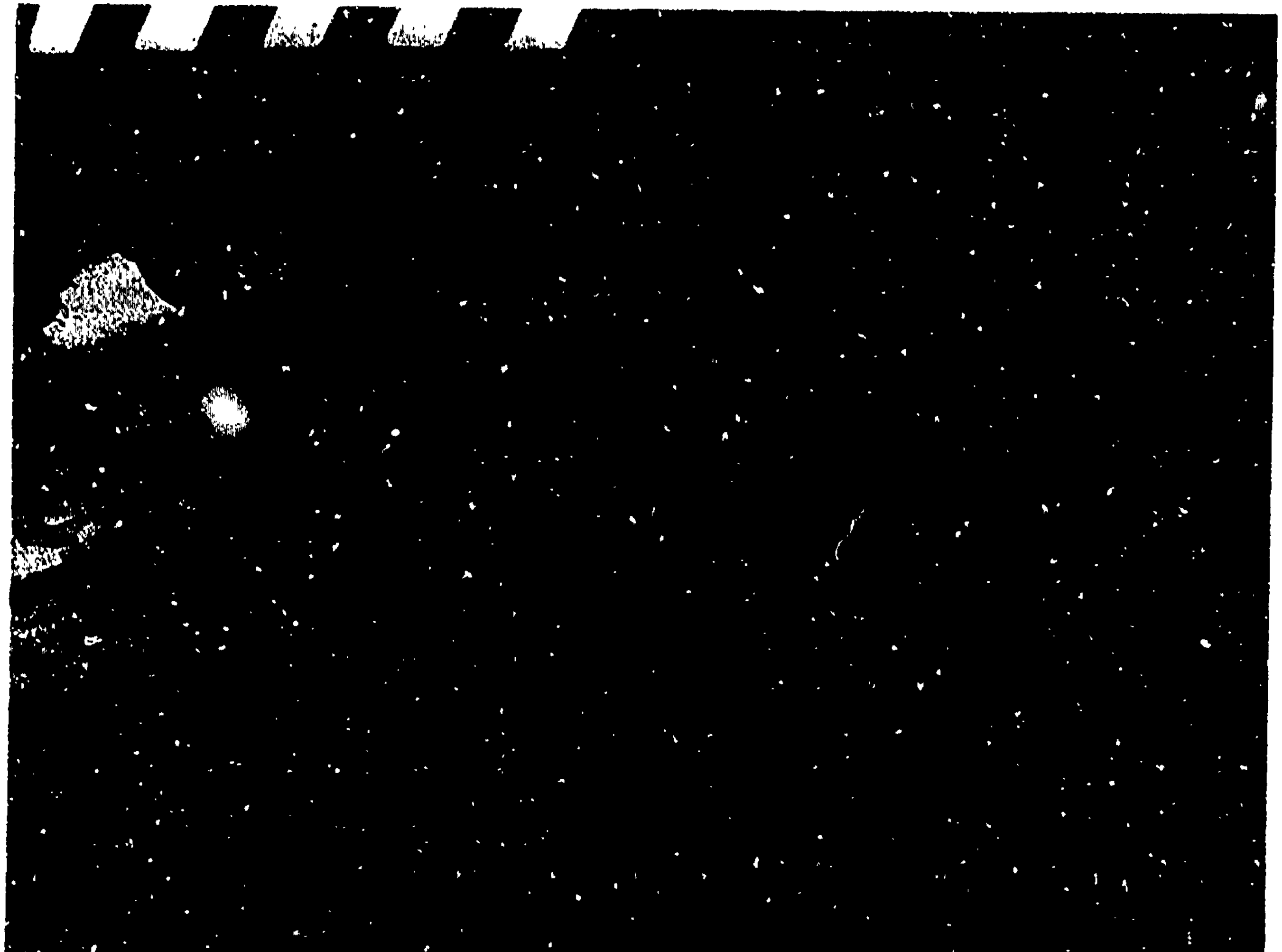

Figure 29. Lumber used for wheel-stop when positioning the truck under the hopper.

Time to Load - Tests With Top

The time between when the container first strikes a bumper and when it is in the position to be locked on the truck is defined as "time to load." This time averaged 56 seconds for the 25 trials.

Time in Guides - Tests With Top

The time between when the container was first at the guides and in the position to be locked to the truck averaged 38 seconds. This can be considered the time spent in the fine positioning operation, i. e., turning the wheels to move the guides to get the container squarely on the chassis.

Total Cycle Time - Tests With Top

The total cycle time begins at time zero and ends when the container is out of and clear of the hopper. Average for this time was 2 minutes 48 seconds.

POST-OSDOC II TESTS - NO HOPPER TOP

The hopper top was removed and 25 loading trials were done without it. This test was originally part of OSDOC II, but time limitations forced cancellation. Figure 11 is a photograph of the test setup without the top.

The top was removed in 39 minutes. One welder cut the 16 bolts which held the top to the base. The top was lifted off by the crane with no difficulty.

Time to Postion Truck - Tests Without Top

The average time to position the truck was 14 seconds, beginning at "time zero" and end when the truck was in position, ready to load.

This time is considerably less (10 seconds less) than the tests with the hopper top. The improvement is not related to the fact that the top was off. Rather, it can be attributed to the fact that the truck driver on these tests was highly skilled. He had approximately eight years experience as a driver, most of which was driving commercial trucks before he entered the service.

Time to Load - Tests Without Top

The time to load is defined as the time elapsed between when the container was over the guides and when it was positioned on the truck and ready to be secured. The average without the top was 63 seconds for the 25 trials.

The 63 second average is more than 56 second "time to load" for the trials with the top. It appears that the difference can be attributed to the beneficial effects of the top when used to center the container over the fine positioning guides. Without the top it was necessary for three of the crew to pull on the taglines to orient the (empty) container in the proper direction. This took more time than using the bumpers on the top to guide and swing the container into position.

Time in Guides - Tests Without Top

The "time in guides" is defined the same for both the tests - top or no top. It is the time spent doing whatever manipulation is required of the hinged guides to get the container squarely onto the truck. The average time for the 25 runs without the top was 37 seconds. This is within one second of the 38-second average for the 25 runs with the top.

Total Elapsed Time - Tests Without Top

Total elapsed time, beginning at "time zero" and ending when the container was up and clear of the hopper, averaged 2 minutes 3 seconds. This is less than the 2:48 required with the top.

The difference can be attributed to part to at least three differences between the top vs no top tests. First, the driver was quicker and had no trouble in driving under the hopper. Second, and probably most significant, the time to lower the container into the guides and lift it out is considerably less than without the top than with it. To clear, for example, the crane operator had only to lift the container about 2½ feet from the truck before he could start to swing the container over the dock. He, therefore, started to come in lower with the container and this reduced the time spent in lifting and lowering through the guides.

Third, it was clear that the crane operator was becoming more skilled at placing the container over the hopper - top or no top. He had over 50 trials with it, and was quite accurate in his placement of the container.

TESTS WITH NO HOPPER

Eighteen (18) loadings were done without the hopper. The truck was parked on the 7x15 barge and the crane operator went through the same motions in loading: swinging the container from over the dock to over the truck when lowering it to the truck. Three SEABEES were on the 7x15 barge to handle taglines and push the container into position on the trailer.

The timing of this exercise was necessarily different than for tests with the hopper. "Time zero," when the timing began, started with the crane swinging the container from over the deck. The timing ended when the container was on the truck, in position to be locked. The average time for loading in this fashion was 75 seconds. The average elapsed time from instant the container was over the truck until it was in the locking position was 56 seconds.

It is difficult to compare the loading operation without the hopper with the two loading operations with the hopper. The three do have one thing in common in that the container was positioned over the trailer and lowered downward to the final locking position. The average times are:

Hopper with top (average elasped time from instant container hits bumper until it is in locking position - 25 runs) . . . . 56 sec

Hopper without top (average elapsed time from instant container is over hopper guides until the container is in locking position - 25 runs). . . . . 63 sec

No hopper (average elapsed time from instant container is over trailer until it is in locking position - 18 runs) . . . . 56 sec

In other words, with an <u>empty</u> container, suspended from a crane on land, it makes no difference whether the hopper with the top or no hopper at all is used if only the time over the trailer is considered. On the other hand, it takes slightly longer to load the truck with the hopper using no top and only fine positioning guides.

The operation of the hopper with the top was fast because it was not difficult to drop the container through the bumpers, which aligned the container and guided it right to the fine positioning assembly.

On the other hand, operating the hopper without the top took slightly longer because the crane operator and crew had to position the container somewhat before it could be lowered into the fine positioning guides. This positioning operation added an average of 7 seconds to the loading operation.

In the non-hopper loadings, the deck crew pushed the 4,700 pound empty container with one hand while holding the tagline clear with the other. They usually pushed the container sideways 4-6 inches until it appeared as though the lower corner fittings were over the twistlocks. They would stop pushing, hold the container in position and signal the crane operator to lower the container.

Usually the crane operator would drop rather than "lower" the containers. Most of the time all three crew members were aware that the container was to be dropped; some of the time one may not. Thus, there was a certain element of danger in this loading procedure which could be eliminated by making it unnecessary for the deck crew to come in contact with the container.

In post-test interviews the crew stated that two things usually slow down loading operations. First, loaded containers are difficult to push into position, so more maneuvering of the crane is required to get the container close to the twist locks. Secondly, winds can exert forces on the container which make it difficult to move, position and maintain position.

Comparison of Time to Position Truck - Post-OSDOC II and OSDOC II Tests

The improvement in truck positioning which resulted from using the lumber as a wheel stop is best shown by comparing average times. During the causeway operations at sea, the trucks of the first causeway were positioned under the hopper in an average of 1 minute 22 seconds, the second causeway, 38 seconds. Measurement of truck positioning time began when the bumper of the truck was first under the hopper and ended when the truck was stopped, ready to be loaded. For the post-OSDOC II tests, in which the lumber was used, the truck positioning times were 24 seconds for the inexperienced driver and 14 seconds for the skillful driver, for an overall average of 19 seconds.

Another reason for the improvements in positioning may be due to the effect of the learning curve applied to the driver and the man directing him. Some of the drivers in the tests at sea drove through the hopper only once. The drivers in the post-OSDOC II tests drove through it 25 times each. While the data to not strongly suggest a learning curve for the driver and man directing him, there appears to be some improvement after the first few trials -- at least for the inexperienced driver.

Summary of Times - Post-OSDOC II Tests

The various times discussed above are summarized below. All defined times are elapsed times from time zero. All trials with the hopper include positioning the truck and swinging container 90° with the crane before lowering.

Hopper With Top (Post-OSDOC II Tests, 25 Trials)

A. Time truck stops - in position
B. Time container strikes a bumper
C. Time container in guides
D. Time container chassis, ready to be locked on
E. Time container free and clear of hopper

Average of A = 24 seconds
Average of D = 1 minute 48 seconds
Average of E = 2 minutes 48 seconds
Average D - C = 38 seconds
Average D - B = 56 seconds
Average E - B = 1 minute 56 seconds

Hopper Without Top (Post-OSDOC II Tests, 25 Trials)

A. Time truck stops - in position
B. Time container over hopper guides
C. Time container in guides
D. Time container on chassis, ready to be locked on
E. Time container free and clear of hopper

Average of A = 14 seconds
Average of D = 1 minute 28 seconds
Average of E = 2 minutes 3 seconds
Average of D - B = 63 seconds
Average of D - C = 37 seconds
Average of E - B = 1 minute 38 seconds

No Hopper (Post-OSDOC II Tests, 18 Trials)

All defined times are elapsed times, beginning when the crane operator began swinging the container 90° from over the dock:

A. Time container over trailer
B. Time crane operator begins to lower container
C. On chassis, ready to be locked on

Average of C = 1 minute 15 seconds
Average of C - A = 56 seconds
Average of C - B = 42 seconds

It should be noted that generally it takes longer to raise the container off the truck and through the hopper than it takes to disconnect the spreader bar and raise it free and clear of the hopper. When raising the container off the truck and up through the hopper, the crane operator was careful and raised the container slowly. When raising a disconnected spreader off the container and up through the bumpers, less care had to be taken since the spreader is up high already and requires less travel distance to get it up and out of the hopper. In the case of the hopper without the top, there is little difference between lifting the container off the truck and clear of the guides or disconnect the spreader and lift it free.

For example, with the top on the hopper, the container must be lifted a total of 15 feet off the truck before it is clear of the bumper arms. On the other hand, the spreader bar has to be lifted only 7 feet before it is clear of the arms of the bumpers. The extra lifting distance, combined with the slower lifting rate used to lift the container off the truck and through the hopper, result in a time difference between the hopper loadings of the post-OSDOC II tests and what would actually occur during a sustained loading operation. Based on observations during the second day of hopper operations at sea, this difference is estimated to be 20 seconds less for the case in which the spreader is disconnected as raised clear. Consequently, from the time a container first strikes a bumper until the spreader bar is clear and free of the hopper will be 1 minute 36 seconds instead of 1 minute 56 seconds as given above (time E - B for the hopper with the top).

EFFECTS OF WEATHER

Barge motions during the post-OSDOC II tests at Little Creek were virtually non-existant. This is one reason - the most important reason - that the loading operations without the hopper went quickly.

V. ESTIMATE OF LOADING CYCLE TIMES AT SEA

The loading cycle times measured at the post-OSDOC II tests can be used as the basis for estimating the total cycle time for a loading at sea during a sustained operation. Such an estimate is based on the assumption that as far as the operation of the hopper is concerned, i. e., positioning the truck and operating the guide assemblies -- there is no significant difference between operation at sea and the operation in the harbor. This appears to be a reasonable assumption based on the observations and data gathered during all hopper tests.

An important difference worth noting is that in the following estimate the truck would not be stopped under the hopper by simply judging the proper loading position, as was done in the two days of hopper operations at sea; instead, the positive stopping device used in the post-OSDOC II test would be employed.

With these qualifications in mind, it is interesting to estimate the probably total cycle time based on the post-OSDOC II tests, which consist of a reasonably large number of trials, and operational times of the crane on the DeLong barge, which was used a large number of times in operations other than those involving the hopper. Personnel evaluating the crane have concluded that on the average the cycle time for the crane is 2 minutes and 50 seconds. The cycle starts with the spreader bar 5 feet above the containership cell. The spreader is lowered into the cell, secured to a container, the container lifted and swung over to the hopper. This takes 2 minutes 20 seconds. An additional 30 seconds is required to swing the empty spreader back to a point 5 feet over the cell, making the grand total 2 minutes 50 seconds. The crane cycle time can be added to the hopper loading time to calculate the total cycle time for loading one truck through the hopper. In the post-OSDOC II tests at Little Creek, measurements were made between the instant the container first strikes a bumper, is loaded onto the chassis, and then is lifted up and clear of the hopper. A conservative reduction of 20 seconds is made for disconnecting the spreader bar from the container and raising it rather than the container clear and free of the hopper. This is the time discussed in the previous section, which is 1 minute 36 seconds. Therefore, the estimated total cycle time is 2 minutes 50 seconds plus 1 minute 36 seconds, or a total of 4 minutes 26 seconds.

The second causeway on the second day (11 October) of hopper operations at sea was the closest of all the tests to a sustained loading sequence. The average was 5 minutes 46 seconds per truck for six trailers. The estimated time of 4 minutes 26 seconds is over one minute less but appears to be a realistic figure. In fact, it may be conservative: on the first causeway, the last two MILVAN chassis were loaded in a total elapsed time of 7 minutes, for an average of 3 minutes 30 seconds per truck. In these runs everything went as planned, particularly over the containership, where the second container was smoothly and quickly lifted out of the cell.

It is important to remember that the estimated cycle time is based solely on changes at the hopper. The most important change is the use of a crew which has used the hopper more than a few times. Even further reductions in truck loading time would be possible if the crane cycle were made more efficient. Almost 3 minutes of the total cycle time of 4 mintues 26 seconds is taken up by the crane. Perhaps the change of greatest benefit would be to put another hopper top over the cell of the containership. This would reduce the time required to position the spreader bar over the cell before it can be lowered. This approach was strongly endorsed by one of the crane operators.

Finally, it should be noted that the estimated cycle time is based on the use of the hopper with the top. Testing of the hopper without the top was not done at sea due to schedule changes during OSDOC II. Until the feasibility of using the hopper without the top is demonstrated, conjecture on cycle loading times should be avoided.

VI. CONCLUSIONS - OSDOC II AND POST-OSDOC II OPERATIONAL TESTS

It is concluded that:

1. The hopper greatly aids the placing of containers by floating crane onto truck trailers. This is particulary true if the trailer is a MILVAN chassis.

2. Placement of a container through the hopper top is an easy and efficient operation which requires little, if any, reliance on taglines to rotate the container in the proper direction. The crane operator alone can maneuver the container through the top.

3. One man per corner is sufficient to operate the fine positioning guides of the hopper. Each man can push his guide assembly into position, operate the fore-aft and sideways controls and push the assembly to the open position once the container is placed on the truck. One additional man should direct the truck driver in and out of the hopper as well as coordinate the efforts of the four other men.

4. Positioning the truck under the hopper presents no unusual demands on the truck driver. A positive stopping method is desirable. The latter could be a piece of wood placed on the deck which stops the truck at the proper loading position.

5. The hopper can be assembled with no unusual demands on personnel or equipment. With minor changes, subsequent assemblies should be faster than the first, which took 96 man-hours.

6. The possibility of damage to a container as it is lowered through or lifted out of the hopper is remote.

7. The gross weight of the container has no influence on the ease of speed of loading through the hopper.

8. Barge motions have little if any influence on the ease and speed of loading through the hopper once the container is within the confines of the six bumpers.

9. No major modifications are required to the hopper. The only change to the unit will be to put a small stopping device in the latch which locks the fine positioning assembly in and out of position.

10. The hopper can withstand indefinite usage of the type experienced in OSDOC II.

11. The type of spreader bar used to handle the container has no influence on the hopper operation.

12. The M127, MILVAN chassis, M52 truck tractor, and M123 truck tractor, as well as similar equipment, can be loaded through the hopper without qualification.

13. MILVAN chassis takes longer to load through the hopper than flatbed trailers. (However, it takes much too long to secure containers to the flatbed trailers.)

14. The truck can be positioned under the hopper in far less time than is required for the crane to swing over to the ship, take a container out of a cell or off the deck, and swing back over to the hopper. Consequently, truck positioning time is not critical to hopper efficiency.

Appendix

ERROR IN USING V_A FOR V_{cg}

The problem of a swinging suspended concrete weight can be idealized by a two-degree of freedom pendulum as shown in Figure A-1. The objective here is to obtain expressions for velocity of point "A" and velocity of the center of gravity (cg), respectively so that a meaningful comparison can be made and the error in using V_A instead of V_{cg} can be estimated.

To obtain the expressions for V_A and V_{cg}, the following approach is used:

(1) Formulate the governing differential equations and obtain the general solution.

(2) Impose the initial conditions and obtain the solution for specific problem in question, i. e., the swinging weight problem.

(3) Formulate expressions for V_A and V_{cg}.

(4) Assess the difference between V_A and V_{cg}.

FORMULATION

The kinetic energy of the system (Figure A-1) can be expressed as

$$KE = T = \frac{W}{2g} V_{cg}^{\ 2} + \tfrac{1}{2} I_{xc} \dot{\theta}^2 \qquad \text{(A-1)}$$

the term $W/2g\ (V_{cg})^2$ represents the KE due to the curvilinear motion of cg, and second term represents the KE due to rotation about the cg.

Referring to Figure A-1, by cosine law,

$$\text{(A-2)}$$

$$V_{cg}^{\ 2} = (\ell\dot{\phi})^2 + 2\ (\ell\dot{\phi})\ (a\ \dot{\theta})\ \cos\ (\theta - \phi) + (a\ \dot{\theta})^2$$

$$= (\ell\ \dot{\phi})^2 + 2\ (\ell\dot{\phi})(a\dot{\theta}) + (a\dot{\theta})^2$$

on account of the smallness of $(\theta - \phi)$, i. e., $\cos\ (\theta - \phi) \simeq 1$.

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By (A-1) and (A-2)

$$T = \frac{W}{2g}\left[\ell^2\dot{\phi}^2 + 2\ell a\dot{\phi}\dot{\theta} + a^2\dot{\theta}^2\right] + \tfrac{1}{2} I_{xc}\dot{\theta}^2 \tag{A-3}$$

The potential energy of the system is

$$\begin{aligned} PE = V &= W\left[\ell(1-\cos\phi) + a(1-\cos\theta)\right] \\ &\doteq \frac{W}{2}\left[\ell\phi^2 + a\theta^2\right] \end{aligned} \tag{A-4}$$

Here again, ϕ and θ are assumed to be small so that higher order terms can be neglected as compared to unity. With (A-3) and (A-4), letting $q_1 = \phi$, $q_2 = \theta$, the Lagrangian equation.

$$\frac{d}{dt}\frac{\partial T}{\partial \dot{q}s} - \frac{\partial T}{\partial q_s} + \frac{dV}{\partial q_s} = 0, \quad s = 1,2 \tag{A-5}$$

yield the following differential equation for the system:

$$\begin{aligned} &\frac{W}{g}\ell^2\ddot{\phi} + \frac{Wa\ell}{g}\ddot{\theta} + W\ell\phi = 0 \\ &\frac{Wa\ell}{g}\ddot{\phi} + \left(\frac{Wa^2}{g} + I_{xc}\right)\ddot{\theta} + Wa\theta = 0 \end{aligned} \tag{A-6}$$

Equations (A-6) are the governing differential equations.

THE GENERAL SOLUTION

By assuming a solution of the form

$$\begin{aligned} \phi &= A\sin(pt+\alpha) \\ \theta &= B\sin(pt+\alpha) \end{aligned} \tag{A-7}$$

the general solution to equations (A-6) is obtained as follows:

$$\phi = 0.967\, B_1 \sin(p_1 t + \alpha_1) - 0.052\, B_2 \sin(p_2 t + \alpha_2) \qquad \text{(A-8)}$$

$$\theta = B_1 \sin(p_1 t + \alpha_1) + B_2 \sin(p_2 t + \alpha_2)$$

where

p_1 = 0.714 radians/sec - the fundamental frequency

p_2 = 4.355 radians/sec

B_1, B_2, α_1 and α_2 are the four constants of integration to be determined by the initial conditions.

THE SOLUTION

The initial conditions are:

$$\phi_{t=o} = 0.0868 \text{ radians} \qquad \text{(A-9)}$$

$$\theta_{t=o} = 0$$

$$\dot{\phi}_{t=o} = 0$$

$$\dot{\theta}_{t=o} = 0$$

Using (A-9), the four integration constants in (A-8) are determined as below:

$$\alpha_1 = \alpha_2 = \frac{\pi}{2} \qquad \text{(A-10)}$$

$$B_1 = -B_2 = 0.0852$$

and the solution becomes

(A-11)

$$\phi = 0.0852\left[0.967 \cos p_1 t + 0.052 \cos p_2 t\right]$$

$$\theta = 0.0852\left[\cos p_1 t - \cos p_2 t\right]$$

THE VELOCITIES V_A, V_{cg}

Referring to Figure A-1, for small oscillation, the velocity of point A can be expressed as:

(A-12)

$$V_A = \ell \dot{\phi} + \ell_A \dot{\theta}$$

$$= -3.843 \sin p_1 t + 0.7532 \sin p_2 t$$

and the velocity of the cg as:

(A-13)

$$V_{cg} = \ell \dot{\phi} + a \dot{\theta}$$

$$= -3.714 \sin p_1 t - 0.03154 \sin p_2 t$$

ERROR IN USING V_A FOR V_{cg}

The velocities V_A and V_{cg} are plotted and shown in Figure 18. For convenience, the curve for V_A^{cg} is approximated by connecting points with straight line segments. By defining the error, E, as the ratio of

$$\frac{V_A - V_{cg}}{V_{cg}} = E,$$

Figure 18 shows a fairly good general agreement between V_A and V_{cg} except at a few peak spots where a maximum E of about 30% is shown.

From another viewpoint, the difference between V_A and V_{cg} is, by (A-12) and (A-13).

(A-14)

$$V_A - V_{cg} = -0.129 \sin p_1 t + 0.7847 \sin p_2 t$$

The coefficient of $(V_A - V_{cg})$ for the fundamental mode, the dominent mode, is -0.129, which is only 3.47% that of V_{cg}, that is, if we write

$$V_A - V_{cg} = A_1 \sin p_1 t + A_2 \sin p_2 t \qquad \text{(A-15)}$$

$$V_{cg} = B_1 \sin p_1 t + B_2 \sin p_2 t$$

$$\frac{A_1}{B_1} = 3.47\%$$

Based on this, it is believed that the overall error introduced in using V_A in place of V_{cg} would not exceed 4%.

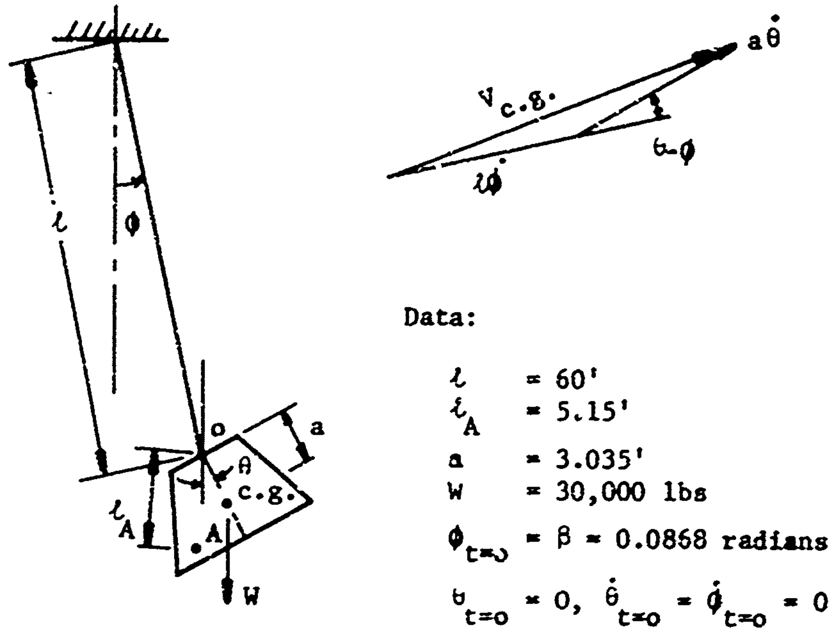

Figure A-1. Pendulum with 2-degrees of freedom.

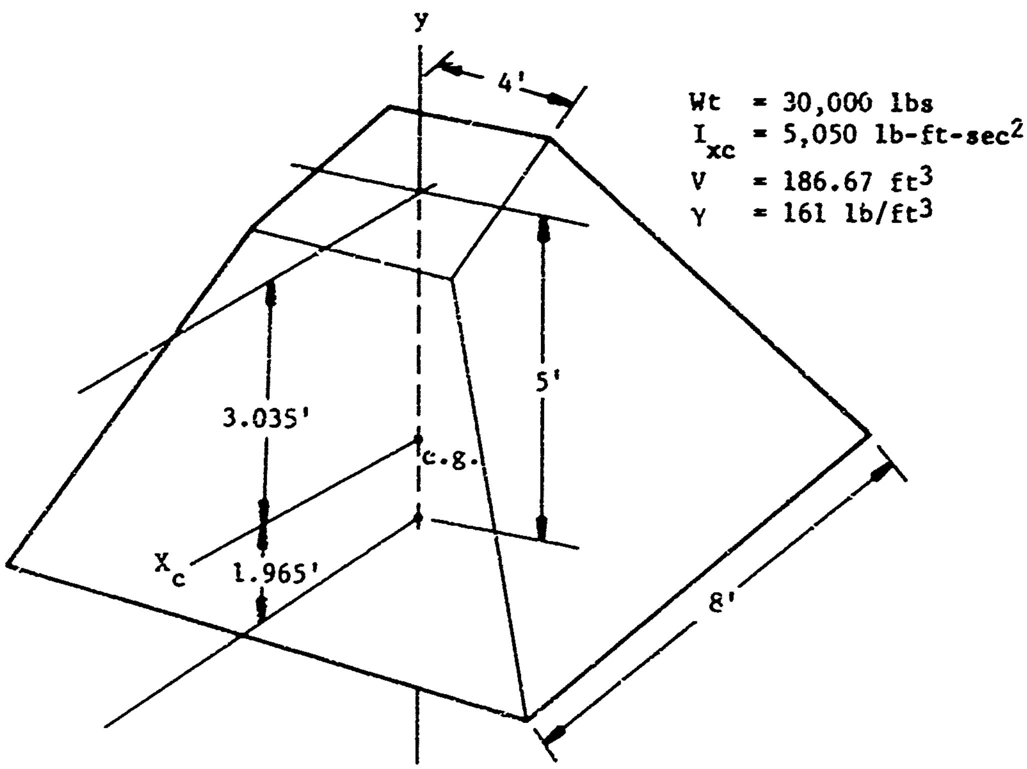

Figure A-2. Weight